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SEWAGE WORKS OPERATORS' COURSE

NO. 1

TORONTO—FEBRUARY 20TH TO 24TH, 1956

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SEWAGE WORKS OPERATORS' COURSE

- No. 1 -

February 20th - 24th, 1956

Toronto, Ontario.

The first course for Sewage Works Operators was held at the Provincial Institute of Trades, 21 Nassau Street, Toronto, on February 20th to 24th. The notes prepared by the instructors are reproduced for use by the students. The course was sponsored by the Sanitary Engineering Division of the Ontario Department of Health which has recently been changed to the Ontario Water Resources Commission.

For further information
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SEWAGE WORKS OPERATOR'S COURSE

- NO. 1 -

TABLE OF CONTENTS

Instructor	Subject
DR. A. E. BERRY	INTRODUCTION
MR. A. V. DELAPORTE	SEWAGE: CHEMICAL AND PHYSICAL ASPECTS
MR. J. G. DUNCAN	SEWAGE CHEMISTRY
MR. J. H. NEIL	BIOLOGY OF RECEIVING WATERS
MR. D. S. CAVERLY	PUBLIC SEWERAGE SYSTEMS
MR. D. P. SCOTT	SEWER SYSTEMS: OPERATION AND MAINTENANCE
MR. G. G. REID	SEWAGE PUMPS
MR. J. G. DUNCAN	CHLORINATION OF SEWAGE
MR. G. T. C. SCOTT	INSTRUMENTATION OF SEWAGE WORKS
DR. A. E. BERRY	SEWER RATE: SECTION 389
DR. A. E. BERRY	SEWAGE SERVICE RATE
MR. R. V. ANDERSON	DIGESTION: THEORY AND DESIGN
MR. D. P. SCOTT	DIGESTION: OPERATION AND MAINTENANCE
MR. J. W. MACLAREN	ACTIVATED SLUDGE: DESIGN AND OPERATION
MR. ROY G. TREDGET	TRICKLING FILTERS
MR. D. P. SCOTT	PLANT MAINTENANCE
DR. A. E. BERRY	PLUMBING AND CROSS CONNECTIONS
MR. J. G. POWELL	HYDRAULICS

MR. E. H. BALDOCK	ODOUR CONTROL
MR. K. H. SHARPE	SEPTIC TANK
MR. F. HORGAN	RECORDS AND REPORTS
MR. M. W. WALKINSHAW	MATHEMATICS
MR. L. E. OWERS	SAFETY
MR. A. S. O'HARA	ENTERIC DISEASES
DR. A. E. BERRY	LEGISLATION
MR. E. G. HACHBORN	INDUSTRIAL WASTES: MUNICIPAL BY-LAWS
MR. A. V. DELAPORTE	INDUSTRIAL WASTES

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SEWAGE WORKS OPERATORS' COURSE

- NO. 1 -

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SEWAGE WORKS OPERATORS' COURSE

- NO. 1 -

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SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: INTRODUCTION

Instructor: A. E. Berry

This is the first course for sewage works operators sponsored by the Ontario Department of Health. It is part of a plan to provide instruction for key personnel in the field of environmental sanitation. It is under the direction of the Environmental Sanitation Training Centre of the Department of Health. The facilities of the Provincial Institute of Trades have been made available for the instruction. This course of training is similar to what is being done elsewhere - in the United States and Canada. It is expected that courses of training for operators will be available in due time in other provinces, so that the instruction can be coordinated and be considered a national procedure.

The Course of Instruction

This first course is of one week's duration. It will consist of a series of lectures, and one seminar for a general discussion of problems in sewage works operation.

The instructors have been generous enough to contribute their time to assist the operators. They come from the staff of the Department of Health, from a number of municipalities, and consulting engineers. They have a wide experience in this field. This voluntary action on the part of the instructors is both an indication of their interest in these matters and their recognition of the need for cooperation of all if the desired objective is to be accomplished.

Objectives of the Course

The major objective in this course is to provide the instruction and basic training for efficient and intelligent operation of sewage works. Basic principles will be outlined and information supplied on day to day problems. The disposal of sewage and other liquid wastes is an important public service. It is increasing in significance as the need for action is recognized. Operators must be well trained to meet this responsibility.

The instructors will supply guidance, but much will depend on the operator himself. All students on the course

are urged to give diligent attention to the work and to ask questions freely. The course is concentrated, and it will be a strenuous one for those who have not been accustomed to listening to lectures for 7 hours a day. It was felt that a course of one week was best suited for this purpose.

This course and others which are expected to follow later will train the operator to carry on his duties more effectively. It is a worthy objective to serve the public in the most efficient manner. To do this an operator must be well trained in his work, trained not only to do the right thing, but to understand why certain procedures are necessary.

The Contents of the Course

This course has been arranged chiefly to serve two groups:

(a) the operator or superintendent of a sewer system
(b) the operator of a waste treatment plant, including domestic sewage and industrial wastes.

A review of the subjects on the time table will reveal the division of instruction for these two groups. It will be seen also that there are a number of subjects of general interest - equally applicable to both groups. It is important that each student endeavour to familiarize himself with all aspects of this work irrespective of the specific section of the field in which he is now directly concerned. Only in this way can the instruction be of maximum benefit.

Additional Courses and Certification

It is recognized that the amount of instruction which can be given in one week is limited. Fortunately the student has experience to start with. This school is to give him supplementary training and thereby to make him a more efficient unit in the public service of this province.

When the full training has been completed the operator should receive due recognition. This can take the form of a certificate of qualification or competency. If this certificate is to have a worthwhile meaning it must be issued only after adequate training and assurance of knowledge and skill. Accordingly it cannot be expected that a course of one week's training is sufficient. Two or three such courses may be necessary to complete the minimum curriculum. An opportunity will be given to take these advanced courses later.

Eventually it is hoped to have all operators fully trained for assuming control of sewage treatment plants, industrial waste purification works, and sewerage systems.

It may be of interest to know that similar programs are under way for water works operators and others engaged in the field of environmental sanitation. Courses of training are receiving increasing support here and elsewhere. In most places certification is on a voluntary basis. This will be the procedure in Ontario.

The trained operator can expect advantages to follow his certification. He can expect promotion, a better position in the sewage works field, which in turn brings higher remuneration. Best of all, however, he will have the inner satisfaction of greater knowledge, and the ability to do his work more efficiently.

The Responsibility of the Operator

The sewage works operator has an important responsibility to his employer and to the public. This includes everyone in this field whether his work involves sewers, pumping stations, sewage treatment plants, or industrial waste purification. He is charged with the protection of public health and the welfare and convenience of the public at large.

The operator must be prepared to recognize his responsibilities and to meet his obligations. That is the first requisite of a good operator. He should take pride in his work, knowing the importance that must be attached to it. He cannot expect public approbation because his work is so little understood by the public. But he can feel major satisfaction in work being well done in the public service.

Some Requisites for a Good Operator

Some requisites of a good operator are listed here in general terms. He should cultivate these and ever strive to improve his efficiency. Only perfection is good enough.

(1) He must ensure the protection of public health at all times. He must ever be alert against any action which will jeopardize the health of others. This will include continuous operation of the treatment works, and adequate dosage of chlorine where that treatment is necessary. Improper operation may involve water supplies, recreational facilities, and other matters related to health. By-passing of treatment works may have far-reaching effects.

(2) He must ensure maximum treatment. Sewage purification works are intended for the best treatment that can be obtained. It is the operator's duty to strive for this.

(3) He must aim at efficiency and economy at all times. Inefficiency is wastefulness. There is no place for this about sewage works. Public funds, or company funds should be handled with care.

(4) He must aim for cleanliness and sanitation about the sewage works. No good operator will tolerate dirty and untidy surroundings. He must deal with an offensive waste. Accordingly it is important to handle it in the most sanitary manner.

(5) He must control odors and interference with others. Much can be done in sewage works to keep odours to a minimum. In that way these plants will interfere the least with the neighborhood. That responsibility must be recognized always.

(6) He must be conscious of the need for good public relations. The operator can do much to maintain good relations with the public and with his employers. This is an important obligation in the disposal of offensive wastes. It aids also in securing needed enlargements or modifications in sewage works. Visits from the public will be helpful.

(7) He must be a student always. It is not sufficient to sit back and be satisfied. He should have an inquiring mind, ever anxious to learn and to improve.

(8) He should be interested in research. There is much to be learned about sewage works processes. Much of this can be investigated at treatment works by the operator. He can always ask assistance of others in the solution of these problems.

(9) He should be an enthusiast. The man who is not enthusiastic about his work will find it is dull and monotonous. The more enthusiastic an operator becomes the better the results and the more interesting will he find his work.

Finally a good operator is a combination of many attributes of which the preceding are but a few. Much is expected of him in this forward march to solve our pollution problems and to conserve the sanitation of our water courses.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: SANITARY SEWAGE

Instructor: A. V. DeLaporte

The sanitary sewage of a municipality which consists of the used water from the municipal water works, in too many instances includes storm water and ground water from infiltration. Ordinarily along with the mineral salts in the municipal water supply there is an increment of solids, both dissolved and suspended. This increment in domestic sewage consists primarily of body wastes. In addition, kitchen wastes, laundry wastes, wastes from window and floor washing are present. Where storm water is permitted in the sanitary sewer road washings contribute a substantial load to the sewer. In manufacturing centres, industrial waste liquors complicate the picture.

From a treatment standpoint the various components of sewage fall into several categories and will be discussed under the following headings:

(A) Deoxygenating - B.O.D.
(B) Nitrogen - Nitrogen Cycle.
(C) Suspended Solids.
(D) Toxic, Flamable, Acid or Alkali, Oil and Grease or Other Undesirable Material From Industry.

A. DEOXYGENATING:

Organic matter in sewage provides the food for the flora and fauna normally present in the sewage. All living forms as we know them require oxygen. Some bacteria utilize free oxygen dissolved in the sewage and cannot utilize combined oxygen. These forms are called aerobes or aerobic. Some forms utilize the oxygen combined in the mineral salts and the absence of free oxygen does not affect their metabolism. These forms are anaerobic, or anaerobes. There is a third group of micro-organisms which are capable of utilizing either free oxygen or combined oxygen. These are facultative anaerobes or facultative aerobes depending on the background training of the bacteriologist speaking. To get back to the plant food supplied with the sewage, the organisms utilizing this food require oxygen. The amount of free oxygen required to supply the organisms which are utilizing the food available is the biological oxygen demand. Certain standard methods of analysis have been established to measure the oxygen required at a definite temperature over a measured period of time:

Two Day Biochemical Oxygen or B.O.D. Demand at 20°C.
Five Day Biochemical Oxygen or B.O.D. Demand at 20°C.
Ten Day Biochemical Oxygen or B.O.D. Demand at 20°C.

In research it is sometimes necessary to establish the demand over longer periods, but generally over 99% of the B.O.D. is oxidized in twenty days. In some sewage plants where personnel and equip ment are not available, a relative stability test is made which gives some idea of the deoxygenative properties of the sewage or effluent. It is the deoxygenating material that causes the nuisance. The free dissolved oxygen is utilized and ultimately the anaerobes and facultative anaerobes utilize the oxygen from sulfates, nitrates and carbon dioxide. The sulfates are reduced to sulfides. Hydrogen sulfide is evolved and we have that well-known stench described as rotten egg, with a black unsightly liquid.

In ordinary sewage about 50% of the B.O.D. is in the suspended matter and 50% in solution. These percentages may vary 60 to 40 or 40 to 60. Settling the suspended solids from the sewage will therefore reduce this B.O.D. in the neighbourhood of 50%.

The usual routine B.O.D. is five-day at 20°C. The coefficient of 0.168 pounds of five-day 20°C. B.O.D. per capita per day is used for converting the B.O.D. value of industrial waste to a population equivalent figure. The population equivalent is applicable only to the B.O.D. and does not imply or signify an equivalent bacterial pollution load.

B. NITROGEN:

Nitrogen is an inert gas and comprises about 80% of the atmosphere. Electric discharges cause a reaction between some of the nitrogen in the atmosphere and oxygen and oxides of nitrogen are formed. Similarly certain species of micro-organism - the azotobacter - have the ability to fix nitrogen as oxide in the soil. Oxides of nitrogen are necessary for plant food. The plants build proteins using the available water soluble nitrogen. Animals utilize the plant proteins for food and ultimately the plant or animal nitrogen compounds are broken down by biological activity to polypeptrol - amino acid, ammonium salts - some of the nitrogen being lost as a gas in the process. The ammonium salts are oxidized to nitrites and nitrates. Nitrates are unstable being a transitive on the oxidation to nitrates or a transitive in the reduction of nitrates to ammonium salts or nitrogen gas. This is known as the nitrogen cycle. The determination of the amounts of nitrogen present in the different forms gives a Sanitarian an excellent picture of the degree of decomposition that has taken place. Nitrogen in the laboratory is determined as total nitrogen which is not really total nitrogen but total organic nitrogen. Some laboratories still do a test known as albumenoid nitrogen. There is no such

thing as albumenoid nitrogen but the measure is of the nitrogen material broken down by digestion with alkaline permanganate and measured as ammonium. Albumenoid ammonia is not the product of complete breakdown of this organic nitrogen and is gradually being discarded. Nitrogen is measured as so-called free ammonia. This means saline ammonium. Also the oxides of nitrogen - nitrites and nitrates - are also measured. This gives a fairly complete picture of the state of oxidation of the sewage.

C. SOLIDS: DISSOLVED - SUSPENDED - TOTAL.

Dissolved solids are those compounds in true solution. They are generally composed of mineral salts with the soluble organics. As previously mentioned about 50% oxidizable material is in solution. The mineral salts, if neutral, do not have much significance. However, as the dissolved solids increase, the solubility of oxygen decreases and more important the rate of solution of oxygen is slowed up.

Suspended solids are generally speaking, organic in nature, being fecal matter, paper and vegetable waste. In combined sewer systems, however, one will find road washings, sand, gravel, cinders and material of that kind.

Total solids are the sum of the dissolved and suspended solids.

D. CHLORIDES:

Chlorides are present in the body wastes as common salt. In the early days of the Sanitary Science the determination of chlorine as chloride was of prime importance. An increase in the chloride content of water was regarded with concern. As an example, the late N. J. Howard once stated that the chloride content of raw Toronto water increased about 10% during the summer bathing period. To-day with chlorine compounds being very widely used in Toronto, e.g., salt for de-iceing roads in winter, etc., there is not the same significance attached to these determinations. Temperature of the sewage is of importance in the treatment, storage and transportation of sewage. The biological activity increases, the rate of oxidation increases. Adversely, the rate of solution and solubility of oxygen decreases.

Hydrogen Ion Concentration (pH)

The pH of sewage indicates its relative acidity or alkalinity. It is a measure of intensity rather than of quantity. A pH of 7 is the neutral point. Higher values are in the alkaline range and lower in the acid range. A mathematical definition of pH is the log of the reciprocal of the hydrogen ion concentration.

It is sometimes necessary to examine sewage for contaminates which have a deleterious effect on the structure, operation, or personnel. These substances include oil, grease, tar, acids (pickling liquor), alkali and toxic substances such as cyanide, chromic salts, etc., but that is properly the subject matter for another lecture.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: CHEMISTRY OF SEWAGE

Instructor: J. G. Duncan

In this paper it is not intended to cover completely the chemistry of sewage but rather to introduce the subject for papers that will follow in future courses.

Sampling

An important part of chemistry that operators should know about is sampling. Chemical Analysis can never be any better than the sample. If a sample is not taken properly or labelled properly, the chemical determinations that are to follow may be all wasted effort. The most important thing is that the sample must represent the condition that exists. The next factor is the type and number of samples to be taken.

A grab sample only represents the conditions that exist at the time a sample is taken. A composite sample gives an average condition over a period of time, and is more truly representative if the individual samples are measured in proportion to the flow. If maximum and minimum conditions are required, it is necessary to take a series of samples at timed periods.

The size of sample varies with the determination required. In most cases, a quart sample will be adequate.

Preservatives should not be used unless it is certain that they will not interfere with the determination to be made. In most cases, it is preferable to keep the sample chilled and deliver it to the laboratory as soon as possible.

Make sure the sample is properly labelled. We have received samples and the only identification has been the express company's label on the outside of the parcel. The label should tell who took the sample, where and when the sample was taken, the type of sample and the determinations required if possible. Do not make general requests such as "What is this?" or "Chemical analysis". If you are not sure what analysis you require, discuss your problem with the men in the laboratory or, if this is not possible, send a note with the sample outlining your problem. Make sure the note is enclosed with the sample and not sent separately by mail. When directions are mailed separately, they often arrive too late to be of use.

The analysis to be covered in this lecture are those determinations of nitrogen, oxygen and solids.

Nitrogen is found in sewage in four different forms: free ammonia, nitrite, nitrate and organic or protein nitrogen. In reporting nitrogen, other terms are sometimes used, such as:

Kjeldahl nitrogen. This is the same as organic nitrogen.

Total Kjeldahl determination includes free ammonia and organic nitrogen.

Total nitrogen is the sum of all the nitrogen present as ammonia, nitrite, nitrate and organic.

In order to interpret nitrogen analysis, some knowledge of the nitrogen cycle is necessary. In nature, nitrogen can be converted to ammonia which in turn is oxidized to nitrite and then to nitrate. The nitrate is utilized as food by plants and converted into protein material. The plants are then eaten by animals and the plant protein is converted to animal protein and the cycle is completed when these protein materials are broken down into ammonia or free nitrogen. This roughly describes what happens to nitrogen in passing through the nitrogen cycle.

Sewage entering a sewage plant normally contains organic and ammonia nitrogen. If it is treated in a plant such as an activated sludge plant, the protein material will be destroyed and the nitrogen be present in the effluent as ammonia, nitrite and nitrate. If the sewage is given anaerobic treatment, the protein material is again broken down and the nitrogen in this case is liberated as free nitrogen and escapes in the gases given off in the process. So in both these methods of sewage treatment, the determination of the amount of nitrogen in the effluent and the form in which it is present, is an indication of the amount of treatment the sewage has received.

Oxygen Determination

Dissolved oxygen is the amount of oxygen present in solution. It is useful in determining if sufficient air is being supplied aerobic treatment of sewage. It is also used to determine the effect of a sewage plant effluent on a receiving body. It indicates septicity or photosynthetic activity that is present in the stream or lake. It is also used in BOD determination.

Much work has been done to evaluate the strength of sewage and effluents in terms of the oxygen required to satisfy their biochemical oxygen demand.

Relative Stability is a simple method that has been used in determining the stability of effluents: It consists of adding methylene blue to a sample of effluent in a sealed bottle and incubating until the colour disappears. The number of days required to decolorize the sample is an indication of its stability. One objection to this determination is that it requires up to twenty days for completion. This determination is rapidly being replaced by other more accurate analyses but it is still useful for small plants with limited facilities.

The 5 Day BOD is the method now generally used to determine the strength of sewage and effluent and their effects on receiving waters. It is the amount of dissolved oxygen required to stabilize the organic material present in the sewage by means of aerobic biochemical action. Under the conditions of this test, as set out in "Standard Methods", it would require over 100 days for this test to go to completion. In consequence, a five-day period of incubation has been recommended as a satisfactory period of time. The test consists of diluting the sample to be tested with water saturated with dissolved oxygen and determining the dissolved oxygen in the dilution before and after the five-day incubation period.

This test is much more accurate than Relative Stability but still has the drawback of requiring five days for completion.

Chemical Oxygen Demand (COD) determined by chemical oxidation has been utilized in an attempt to determine the oxygen requirement of sewage and waste in a short period of time. Several procedures have been used but to date none have replaced the BOD. The reason is that with chemical oxidation, a different group of compounds are oxidized than with biochemical oxidation. It is, however, possible with some wastes to develop a factor that will convert chemical oxygen demand to biochemical oxygen demand. COD is useful where information has to be obtained in a hurry. Also with some wastes, it is impossible to make BOD determination and the COD has to be used.

Solids

In considering solids in sewage, one has to remember that the water before it was polluted contained considerable solids as dissolved mineral matter. This material is inert. From the point of view of sewage analysis, the solids we are interested in are the organic solids, both soluble and insoluble, and the suspended solids.

The solids are determined by evaporating a measured volume of the sewage in a tared or weighed dish. The increase in weight of the dish is the total solids. The organic material present is determined roughly by igniting the solids and weighing the dish once more. The loss in weight on ignition is an estimate of the organic material present.

Dissolved solids are determined by filtering a portion of the sample and then determining the solids on the filtered sewage the same as for total solids.

The suspended solids may be estimated by taking the difference between the total solids and soluble solids, or by filtering a measured volume of the sample through a special filter known as a "Gooch Crucible", drying the filter, and the increase in weight of the filter is the suspended solids.

In solid determination, it must be remembered that certain errors occur that cannot be avoided. Volatile solids are lost in evaporation. Some compounds decompose on heating. Other compounds form hydrates withwater when they are crystallized and it is sometimes difficult to remove this water of crystallization completely.

Settleable Solids in an Imhoff Cone.

This is a determination that can be carried out in any sewage plant to determine the volume of settleable solids in a sewage or effluent. All that is required is an Imhoff cone that is filled with one litre of a well-mixed sewage or effluent and allowed to settle for one hour. The bottom of the Imhoff cone is graduated in ml. and the volume of sludge is read from this scale and is reported as ml. per litre or as a percentage. In making this determination on effluents, a note should also be made of appearance and density of the settled sludge.

THE BIOLOGY OF RECEIVING WATERS

- by -

JOHN H. NEIL

INTRODUCTION

Two hours will not be sufficient to go very deeply into the biology of water, but by indicating some idea of the intricate biological relationships that exist in natural waters and discussing what happens when pollution such as the effluent from a disposal plant enters that water, then perhaps a better understanding will be provided of the important responsibility of the sewage plant operator in alleviating pollution.

LIFE IN FRESH WATER

Several thousand species of plants and animals live in fresh water. The plant kingdom has many types of vascular plants such as the cattails and the water lilies and many species of algae that may range in size from microscopic forms that are just visible when magnified 1000 times to some growing to a height of four feet. From the animal kingdom representatives of vertebrate animals such as fish are there, as well as invertebrates like insects, aquatic earthworms, snails, clams and crustaceans.

FOOD CHAINS

It has often been said that "algae is the grass of water". All life on land is ultimately dependent on grass. There would be no rabbits if there weren't grass for them to eat and likewise there would be no foxes if there were no grass, as the fox is dependent on rabbits which in turn are dependent on grass. This is what is known as a food chain. In water a similar food chain exists but it is algae that forms the basis. The algae provides food for the Cladocera (water fleas), these are in turn eaten by minnows which are in turn eaten by the bass, which are ultimately eaten by us if we are lucky enough to catch one. Thus, where man is at the head of the food chain he too is ultimately dependent on algae.

PRODUCTIVITY OF WATER

As algae is the food for all other life in water then theoretically the productivity of a body of water, expressed for example as pounds of fish per acre, should be directly related to the amount of algae present. This is generally true.

The production of algae is dependent upon both physical and chemical conditions in the water. Light is of prime importance to any plant. It is the energy source by which the plant manufactures its food in the form of starches or oils. If the light can penetrate only one foot due to turbidity or colour in the water then the plants can only grow to that depth. On the other hand when other conditions are equal and light can penetrate thirty feet then production of algae will probably be thirty times as great.

Temperature is another important factor not in determining how much algae will be present but in regulating what kind will grow. Water never goes below 32° F and many algae grow just abundantly at this temperature as their relatives do at 80° F in the summer. In this climate however, the surface is often frozen in winter and it is light not temperature that effects the control. In our climate probably the most important factor governing productivity is the plant nutrient supply in the water. Most important of these are the elements nitrogen and phosphorous which sewage effluents supply in considerable quantity to natural waters. In this connection an example of the role that nutrients supplied by a disposal plant play in the development of algae might be cited in Sturgeon Lake. Near Lindsay, a nuissance condition from the excessive growth of algae developed about 1948. In 1950 we began an investigation into the causes in hopes that some method of control could be developed. After two summers work we came to the conclusion that the cause of the excessive growth was the abundance of nutrients present in the lake. The obvious control was to limit the nutrients and the only place this could be done was to remove those supplied by the disposal plant at Lindsay.

Phosphorous appeared to be the key element and a method of chemical precipitation was developed by which it was reduced by 85%. The effect on the algae we believe can be shown though it is difficult to interpret the results after one seasons operation.

EFFECT OF POLLUTION ON NATURAL CONDITIONS

Thus far the discussion has covered the physical and chemical properties of the aquatic environment which govern the productivity of a body of water. In natural conditions this crop is harvested by a host of organisms such as fish, insect larvae and other animal forms living in the water, and thus an intricate biological relationship is developed. What happens when a form of pollution is added? Any change in the environment will produce a corresponding change in the life present. This may be good or bad but unfortunately it is generally bad.

CLASSIFICATION OF POLLUTION

Pollution from a biological standpoint is divided into three classes.

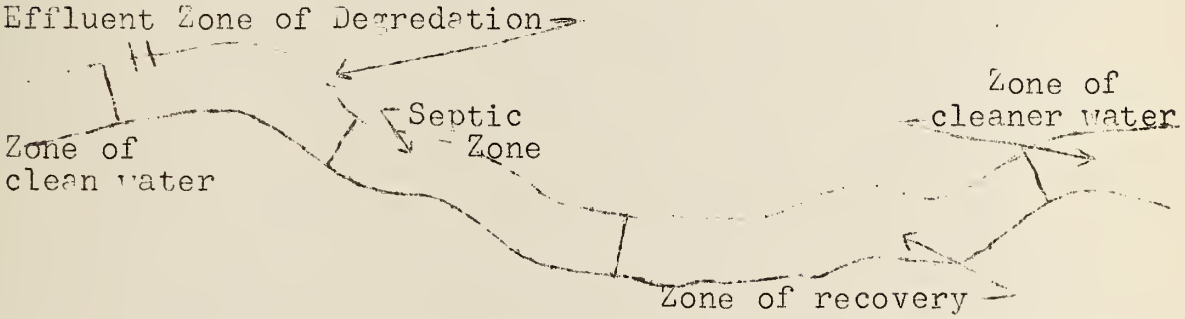
1. Oxygen depletion
2. Toxic Substances.
3. Changed environment.

OXYGEN DEPLETION

The effect of sewage is generally considered as oxygen depletion. While this is generally true it may also carry toxic substances and it may change the bottom environment. These three types of pollution will be discussed in turn with reference to the effect each has on life in the receiving water.

Oxygen depletion is caused by a breakdown or rotting of organic material which required oxygen. In water the only source of oxygen available is that which is dissolved. When the amount of oxygen required is greater than the content of water then anaerobic (meaning without oxygen) conditions occur. When a stream receives more oxygen depleting substance than it can handle, a typical pattern of degredation and recovery occurs.

PATTERN OF A POLLUTED STREAM



In the zone of clear water the oxygen concentration remains at or near saturation at all times. As the water receives the organic waste, the oxygen concentration drops rapidly until little or no oxygen remains. The distance this septic zone extends downstream depends on the amount of organic matter and the dilution it receives in the river. Ultimately the oxygen from the air will diffuse back into the water, the oxygen demand of the putrefying substance will be satisfied and the oxygen concentration will return to a saturated level.

In the septic area of the stream the bottom is grey black and very obnoxious odours occur. These odours are the type that are given off by a digester where anaerobic decomposition also occurs.

When the oxygen reaches about forty percent saturation, the zone of recovery begins. This stream section extends until the oxygen reaches the saturation point where the stream is considered to have returned to normal.

What has happened to the life in the stream during those changes? In the clean water zone probably a large variety of fish, plants, insects and other organisms live more or less balanced in the food chain which I spoke of earlier. Now a catastrophe occurs. The oxygen on which all life is dependant is suddenly removed. What happens is just what would happen in a room if all the oxygen were to be suddenly removed, the people would either get out or die. In the river all organisms that are not specially equipped to live in such an environment disappear.

As the river begins to recover other organisms which are more sensitive than those in the septic zone and yet more tolerant than those requiring clean water, take over. Ultimately a normal association is found again in the clean water area where conditions have returned to normal.

It may interest you to see how some of these animals are able to exist in the polluted areas. In the worst sections only those which are independent of the disolved oxygen live. One example of this is the larvae of a two winged fly called Eristalis. This grub may be found feeding just under the surface of the mud in shallow water. It has a long snorkel or breathing tube which is extended to the surface and through which it draws air. These often occur in great abundance as they have little competition from other animals. Air breathing snails, bugs and beetles may also live in this zone. The snails surface periodically and take a bubble down with them. The bugs and beetles may do the same by drawing air into a cavity in the back of the abdomen or by sticking a bubble to hairs on the underside of the body.

Towards the end of the septic zone and the beginning of the zone of recovery, the foregoing forms may continue to live but another insect larvae and an aquatic earth worm develop in great numbers. Both the Chironomid, as the larvae is called, and the aquatic earth worm have a red pigment in their body fluids which is similar to the red material in our own blood, and this has a great affinity to oxygen. The amount of oxygen required for life in these animals is quite small and thus they are able to extract sufficient for survival. As the oxygen concentration increases those organisms which require more oxygen return to the stream.

In assessing the extent of pollution by the sampling of the life living therein, it is better to use these small invertebrates living on the bottom than fish, as they are unable to move about to any extent. A fish, on the other hand, often makes excursions into unfavourable areas as it can travel rapidly and can leave before any ill effects occur. Just because fish are observed in polluted areas, it does not mean that it is a suitable habitat for them. Fish do however differ in their ability to withstand low oxygen concentrations. Probably the most sensitive of our fish is the speckled trout and as fishermen know, there is not good trout fishing in sewage effluent. The carp is probably the most resistant to low oxygen conditions while other fish lie in an intermediate position. It has been suggested that in order to maintain a fish population successfully the oxygen should not fall below 40% saturation. Many fish will be able to survive concentrations as low as 1.5 ppm for a short time if no work is required, but where energy is used, about twice as much is necessary.

The plants living in our polluted streams are also affected. Where the pollution is heavy as in the septic zone, there are likely to be few plants or algae as byproducts of decomposition such as ammonia, nitrite, and sulphides are poisonous to most plant life. Probably the first algae to be seen will be one called Oscillatoria, an algae that seems to grow only where heavy pollution exists. As you proceed into the recovery zone it is probable that some species of plants will quite abruptly grow in profusion. If the area is slow moving, these plants may be the filamentous types of algae or if the water is moving swiftly, it might be the algae Cladophora or one of the aquatic vascular plants. The profusion of plant life in the recovery zone has led some authorities to name it the algae zone. This heavy growth of plants often extends far beyond the recovery zone as the abundant nutrients may be carried for a long distance downstream. The plant growth is an advantage in some ways and yet produces a pollution problem of their own. As the plants give off oxygen in the process of making food, a heavy growth of plants will add a considerable amount of oxygen to the water. The making of food occurs during the sunlight hours and often the water is supersaturated with oxygen in the daytime. At night, or on cloudy days, the condition is reversed and the plants use oxygen. This makes the situation considerably worse as not only is the decomposing organic matter reducing oxygen, but so are the plants. If an investigation is made of the oxygen conditions in a stream, it should be remembered that the critical time is just before light in the morning. The phenomena of Summer Kill in fish is usually the result of several days of cloudy weather when the plants use most of the oxygen and the fish die of asphyxiation.

TOXIC SUBSTANCES

The second main type of pollution which was referred to earlier, is the effect of toxic materials in the water. A disposal plant is a great leveler to toxic material as in many cases dilution and the biological and chemical activity within the plant, reduce a potentially dangerous substance to safe levels. There are however certain industrial waste products which are very poisonous to all forms of life. To illustrate how toxic some of these can be, cyanide may be used as one example. Under controlled conditions when oxygen temperature and all other conditions are favourable, trout will die at a concentration of .08 ppm in less than three days. This is 0.8 lbs in a million gallons of water. If this is increased to 2 lbs in a million gallons, the trout will die in a matter of an hour or two. Often toxic material comes to the disposal plant as a batch. This may tend to hold together and be discharged in a fairly high concentration. It should be remembered that this will not necessarily be diluted in a stream but may move out and pass down as a block, killing as it goes and only being diluted after a long period of time. A slug of toxic material was once observed which killed every fish as it passed down 35 miles of river over a period of three days and was still killing fish two miles into the lake. The poisoned water had a colour and during those three days, the front and back edges were plainly visible. Many of the substances which are poisonous to aquatic animals are also poisonous to humans and should therefore be prohibited from gaining access to sewers.

In general the effect of toxic substances to the animals in a stream is to kill them all. A few like snails are able to close the door and wait till more favourable conditions occur but in general, a biological desert is created.

In the United States, a survey was made where the investigators endeavoured to collect anything which might be living in the water including fish, all bottom organisms, algae, bacteria and so forth and at the end of an extensive survey, they had not found one living thing in the stream.

Chlorine will sterilize a stream if an overdose is applied. Care must be taken to adjust the chlorinator on sewage effluents so that the chlorine is not in excess of the demand especially where the initial dilution in the stream is not great or where other sewage plants that chlorinate are situated nearby. Last summer a survey was made of a section of stream which received the effluent from five disposal plants within a mile. All plants chlorinated and while the water was clear and the bacterial count was almost nil, I could find only one kind of very resistant blood worm inhabiting the stream. Checks should be made of the chlorine residuals during periods of low flow to ensure that there is not a residual of more than .2 ppm after initial dilution.

CHANGED ENVIRONMENT

The third and last type of pollution is changing the environment. This we generally think of as a coating of the bottom with an inert material such as silt from erosion, solids from a disposal plant, sawdust, ashes, etc. While this may have less spectacular results than the two previously discussed, the damage is often more permanent.

The productivity of the bottom of a stream is dependent on the surface area available for homes for the various animals. If the bottom is covered with a layer of stones and sticks, then the area available for the organisms is much greater than a smooth flat surface. In addition, a smooth bottom is often subject to shifting which most bottom dwellers cannot tolerate. If a disposal plant fills a rubble area to a smooth shifting surface, then you might as well have poured a few pounds of cyanide into the stream.

VALUE OF BIOLOGICAL INVESTIGATION

In some respects, biological investigation of a polluted situation will tell much more than a chemical or bacterial analysis. Chemical constituents in a polluted stream may vary from minute to minute and any sample you take may be representative of the average, or the best, or the worst condition. Also when a stream receives a variety of wastes, it is difficult to know what to look for. A biologist on the other hand can within a few minutes determine the condition of the stream. A thorough biological investigation will not only tell you what the present condition is but allows you to assess the worst condition that has occured in a period of six months or may be a year. Thus you might fool a chemist but you won't fool a biologist.

CONCLUDING REMARKS

I would like to ask you, what is the purpose of sewage treatment? It is to prevent the pollution of water in order to safeguard the health of people and to provide useful water for further commercial and recreational purposes. Most of the subjects which you study this week are concerned with the efficient operation of your plant, but if you want the answer to the effectiveness of treatment, you must turn to the receiving water to find out.

Each one of you has a receiving water for which you are responsible. It has been my observation in travelling around that most of you are proud of your plant and conscienciously try to keep it in good condition. I think that this pride should be extended to the water shed. Many of you are endeavouring to do the best you can but there are others that

find it much easier to by-pass, than to manipulate your plant to the best advantage. You should remember that it may take only one slip to ruin your receiving water for perhaps a year or more.

Probably the greatest single source of pollution to-day, is that contributed by domestic sewage and the ultimate question of whether the lakes and rivers of Ontario will become open sewers or useful water, depends on interest and skill you apply to your duties.

PUBLIC SEWERAGE SYSTEMS

Reference Books:

1. Sewerage & Sewage Treatment - Babbitt
2. Public Health Engineering - Phelps (3 Volumes)
3. Municipal & Rural Sanitations
4. Sewerage & Sewage Treatment - Hardenbergh.
5. American Sewerage Practice (3 Volumes)
   Metcalfe & Eddy.
6. Water Supply & Sewerage - Steel.

Periodicals:

1. Water & Sewage Works
2. Sewage & Industrial Wastes - Journal of C.I.S.S.
3. Municipal Utilities
4. Public Health Engineering Abstracts.

SEWERAGE AND SEWAGE TREATMENT

Control of Public Sewerage Systems by the Ontario Department of Health is maintained by:-

1. Approval of plans and specifications of all proposed work before construction begins. This applies to new systems, extensions of existing works or alterations and renovations. - Public Health Act - Section 106; Parts 2 and 3 (Distribute application forms)

2. Power to issue Mandatory Orders for the construction of any works deemed necessary by the Department. This is similar to the authority for waterworks.

3. Regular inspections of sewerage systems by Engineers of the Department. Special attention is paid to the treatment works.

On March 31st, 1957 this authority was transferred to the newly created Ontario Water Resources Commission.

PARTS OF A SEWERAGE SYSTEM

Sewer - is a channel or conduit intended for the water-carriage conveyance of liquid wastes.

Lateral Sewers or Street Sewers - also referred to as a Branch or Local Sewer. It is a sewer which receives sewage from a relatively small area such as a single street.

It is usually 8" Ø and up for sanitary sewers and 10" Ø and up for combined or storm sewers.

Trunk Sewer - A sewer which receives the dry-weather flow from a number of transverse sewers or outlets and frequently additional predetermined quantities of storm water (if from a combined system), and conducts such waters to a point for treatment and disposal. An intercepting sewer is usually a large sewer, flowing parallel to a natural drainage channel into which a number of main or outfall sewers discharge.

Relief Sewer or Overflow Sewer - A sewer built to carry the flows in excess of the capacity of an existing sewer.

Outfall Sewer - A sewer that receives the sewage from the collection system and conducts it to a point of final discharge or to a disposal plant.

Sanitary Sewer - A sewer intended to carry sanitary sewage only.

Storm Sewer - A sewer intended to carry storm water only.

Combined Sewer - A sewer that receives storm water, surface runoff and sewage.

Separate system of Sewers - is where both storm and sanitary sewers are provided.

Syphon, Inverted Syphon or Depressed Sewer - is a section of a sewer constructed lower than adjacent sections, to pass beneath an obstacle or obstruction. It runs full under the force of gravity and at greater than atmospheric pressure, the sewage entering and leaving at atmospheric pressure.

House Sewer or House Connection - This is the sewer leading from the house to the sewer on the street. It is usually a 6-inch one for an ordinary house.

Sewage Pumping Station - is a pumping station for elevating sewage over high ground through a force main when it cannot flow by gravity.

Sewage Treatment Plant or Disposal Works - is where the sewage is purified mechanically or biologically to render it fit for discharge into the receiving water.

DEFINITION OF TERMS:

Sewer - As a noun refers to a conduit or channel intended to convey sewage.
- The verb to sewer means to supply or equip with sewers.
- As an adjective, sewer means pertaining to sewers, as for example, a sewer system.

Sewage- As a noun, means used water together with such liquid industrial waste, ground water, and dry weather run-off as may be mixed with it.
- As an adjective, sewage means pertaining to sewers or sewerage as, for example, sewage works or sewage association. It is preferable to use the term sewer system rather than sewage system.

Sewerage - As a noun, may mean -

1. The structures, devices, equipment and appurtenances intended for the collection, transportation and pumping of sewage and liquid wastes, but excluding works for the treatment of sewage. - or -

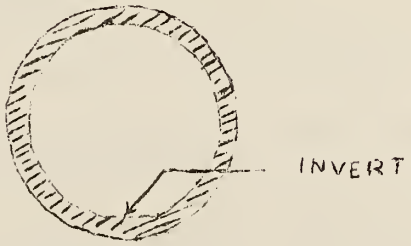
2. The plan or idea for the collection of and the removal of sewage from a community.

- As an adjective, it may be used synonymously with sewage.

Influent - refers to the liquid flowing in.

Effluent - refers to the liquid flowing out.
These terms are more frequently used in connection with a treatment plant.

Invert - is the lowest inside point in a sewer.



The invert is important in the laying of sewers.

TYPES OF SEWAGE

Combined Sewage - a combination of sanitary sewage and surface or storm water, with or without industrial wastes.

Raw Sewage - untreated sewage.

Domestic Sewage - Sewage derivedprincipally from dwellings, business buildings, institutions and the like.

Dry-weather Flow - the normal flow in a sewer during dry weather.

Fresh Sewage - sewage of recent origin containing dissolved oxygen at the point of examination.

Ground Water or Infiltration - water which has leached from the ground into the sewer.

Industrial Sewage or Waste - sewage in which industrial wastes predominate.

Sanitary Sewage - sewage containing predominately excrement and other human wastes.

Septic Sewage - sewage undergoing putrefaction under anaerobic conditions.

Stale Sewage - a sewage containing little or no oxygen, but as yet, free from putrefaction.

Separate System of Sewers vs. Combined System:

A separate system is desirable when -

(a) The sanitary sewage must be concentrated at one outlet such as a treatment plant, and other outlets are available for storm drainage.

(b) The sanitary sewage must be pumped.

(c) The topography is flat, necessitating deep excavations for combined sewers.

(d) The separate sewers must be placed materially deeper than the depth necessary for storm water drains.

(e) Drainage areas are short and steep, facilitating the rapid flow of water over street surfaces to natural drainage channels.

(f) The sewers are to be laid in rock necessitating more difficult excavation for the larger combined sewers.

(g) An existing sewer system can be used to convey the sanitary sewage, but is not large enough to convey storm water.

(h) The finances are such that the greater cost of the combined system cannot be met and sanitary drainage is imperative. Storm sewers can be installed later.

(i) Sewers are being built in advance of the city's settlement to encourage growth.

(j) When comprehensive treatment is required, the receiving stream is small, or where the discharge of combined storm and sanitary wastes via. overflow weirs cause undesirable contamination. All flows in excess of 3 times the dry weather flow are normally by-passed at the treatment plant.

(k) Combined sewers may back up into house sewers flooding basements. The policy in Ontario has been to discourage the installation of combined systems.

A System of Combined Sewers may be used where:

(a) Both the sanitary sewage and the storm water must be pumped.

(b) The district to be sewered is densely built up and there is restricted space for two underground conduits.

(c) Regulators or Weirs can be provided to divert a portion of the flow during a storm, discharging it into a natural drainage channel, while an amount equal to a designed proportion of the dry weather flow (usually 3x) continues to another outlet.

(d) A storm sewer exists or must be constructed and the additional amount of sewage is a small proportion of the maximum flow; or the additional cost of a separate sewer, including the cost of pumping and treatment, will exceed the cost of a combined sewer, and sanitary conditions do not prohibit the discharge of combined sewage at the outlet or outlets.

Physical Characteristics of Sewage contains a small amount of solids in proportion to the tremendous weight of water.

In normal domestic sewage, 1 ton or more of water is required to carry 1 lb. of solids of which 1/2 lb. is in solution, 1/4 lb. will settle and 1/4 lb. is in suspension.

Fresh sewage is grey - appears like soapy dishwater, contains particles of suspended matter visible to the naked eye such as matches, bits of paper, fecal matter, rags etc.

Solids in sewage do not affect the hydraulic formulas developed for the flow of water.

Solids in sewage are organic and inorganic. Organic matter, 40-70% of total solids, cause putrefactive odours and greatest difficulties in treatment.

Inorganic Solids mostly easily settled grit.

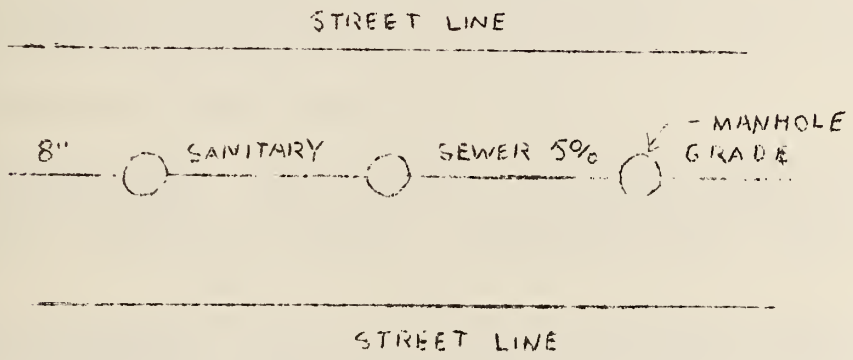
Odour of fresh sewage is faint and not unpleasant, like damp unventilated cellar.

Stale sewage is black and gives off odours of H_2S and other gases. If septic, bubbles of gas will be seen breaking the surface and a black or grey scum may be present.

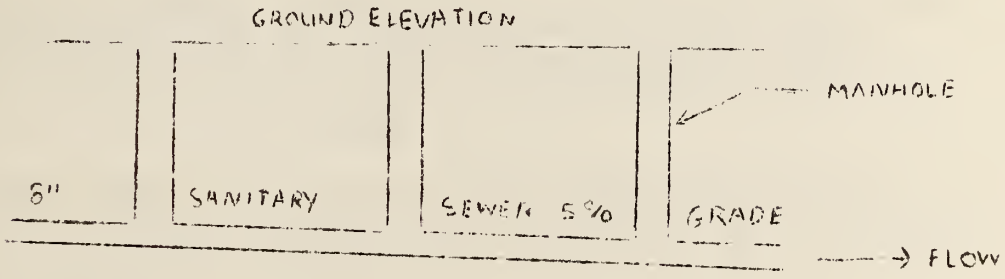
CONSTRUCTION OF SEWERS:

Sewers are laid using a plan and profile.

Plan gives the location on the surface.



Plan gives elevation of the pipe at any point.



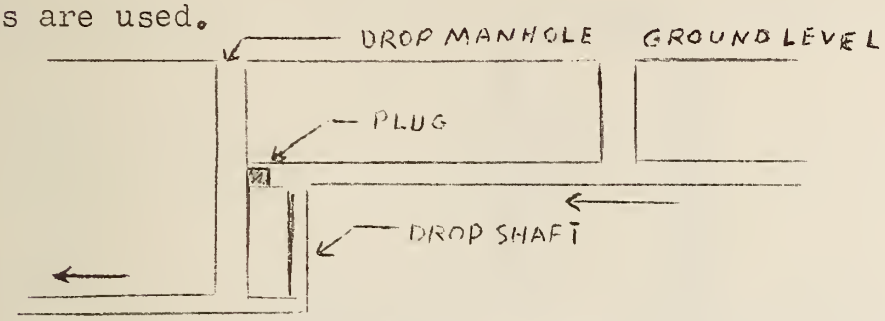
Sewers are laid to a grade or slope so that there will be a self-cleansing velocity of 2-1/2 to 3 feet per second. Velocities in excess of 10 ft./ second are undesirable as scouring results.

Sewers of different sizes have different slopes or grades for the same velocity. Slope for a 9" pipe at 2-1/2 ft./ second velocity is 3.81 ft. per 1000 ft. of length.

For a 18" pipe, slope is 1.70 ft./1000 ft.

For a 30" pipe, slope is 0.94 ft./1000 ft.

To overcome velocities in excess of 10'/second, drop manholes are used.



Street sewers should be laid deep enough to drain the basements of houses about 7' below the surface.

KINDS OF SEWER PIPE:

1. Vitrified Clay Tile - a salt glazed tile, very resistant to corrosion and effects of acid wastes. The jointing compound must be acid proof as well.

Used mostly for small sized up to 24".

2. Concrete Tile - Now in wide use in both small and large sizes, 6" to 90". Concrete is not resitant to acid or other corrosive industrial wastes. Sometimes clay liners are used.

3. Brick Sewers - widely used years ago for tunnels and large sizes. Some had clay lines, now rarely used and replaced to a great extent by reinforced concrete.

4. Asbestos Cement "Transite" - a new development which is coming into wide use, has long lengths and with tight joints, the infiltration is small. It is expensive but is useful in wet soil. It has a lower coefficient of friction and can be used on flatter grades.

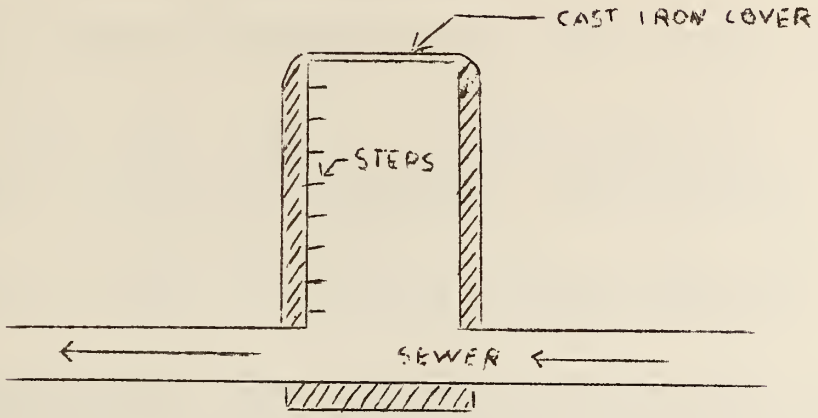
5. Other Types- include cast iron, galvanized iron, wood stave etc. They are only used in special cases, example, cast iron for railway crossings.

SEWER APPURTENANCES:

Manholes - Placed about every 400 feet in the sewer and at every change of direction and grade.

Is used to examine the sewer as well as for cleaning the pipe. Rods, scrapers, as well as flushing is usually employed.

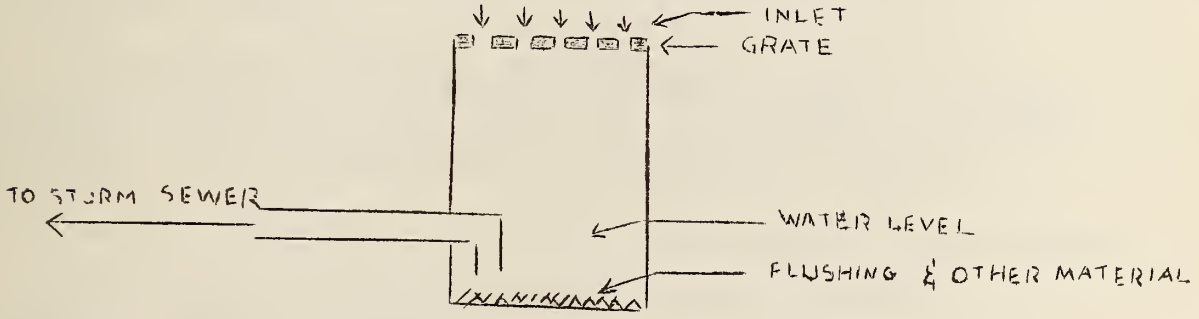
Made of brick concrete, concrete block or corrugated metal. Has a heavy metal cover.



Lamphole - Sometimes used to replace a manhole. Only large enough to lower a lamp to examine the sewer.

Flushing Manhole - Similar to a manhole and placed on the end of a sewer in place of a manhole. Large enough to take a hose to flush the sewer.

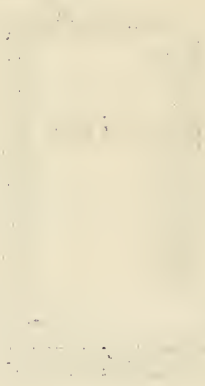
Catch Basin - Are street inlets to storm sewers. The purpose is to trap street flushings which choke the sewer.



Catch basins are usually trapped to prevent odours from the sewer coming up. The sumps are cleared about twice a year either by hand or mechanically - (Suction) Mosquito control may be a problem.

OTHER APPURTENANCES:

Storm Water standby tanks
Grease and oil traps
Flush Tanks
Flow Regulators and overflow weirs
Measuring devices
Syphons



DESIGN OF SEWERS:

Not covered in any great detail. Best to leave to the Design Engineers specializing in this work.

Sanitary Sewers - Design is based on a per capita daily flow with the maximum rate of flow 250% - 400% of the average flow.

Per capita flows vary from 60 - 75 gals./capita/day for strictly residential areas (subdivisions) to around 100 gals./ capita/day for average communities. The difference is an allowance for industrial waste.

To this must be added infiltration and any unusually large industrial wastes.

Storm and Combined Sewers - are designed to handle storm run-off without flooding of streets. The design is based on the maximum rate of rainfall for the area and the imperviousness of the soil etc. The rate of imperviousness (run-off rate) varies from about 20% for park land, to 35% average residential to 60% commercial to 90-100% for completely paved areas.

SEWAGE TREATMENT:

Objectives in Sewage Treatment -

1. As a Protection to Health - Disease producing organisms and substances in sewage may contaminate sources of food and water. Treatment of sewage also reduces the loads on water treatment plants.

2. To Avoid the Creation of Nuisances - Sewage is offensive to the eye and to the nose. It is probably the greatest potential creator of sensory nuisance, its power in this respect being out of proportion to its menace to health.

To prevent pollution of natural waters and bathing beaches.

Contamination of bathing beaches has been common - placarding of Toronto beaches.

Public becoming more aware of our natural resources. Conservation clubs, Hunters & Anglers etc. Protection of Fish and Wildlife.

Inclined to be pressure groups, but can exert great influence and be an aid in obtaining pollution abatement.

3. To avoid Damage Suits When Pollution Deprives Landowner of Natural Use of Stream:

Series of damage suits in Ontario -

Richmond Hill
Woodstock
Huntsville
Kenora.

May have to make some changes in the legislation if the Richmond Hill decision upheld. It would prohibit sewage plant effluents in stream, no matter how well treated. The Public Health Act was amended. An injunction against the operation of a sewage plant, approved by the Department of Health cannot be obtained, but damages may be claimed.

Accomplishments of Sewage Treatment:

The following accomplishments are made by various means in the treatment of sewage:

1. Removal of Solids - (organic and unorganic)
2. Reduction in bacteria.
3. Oxidation of organic substances in the sewage.

Methods of Sewage Treatment:

The basic principles of sewage treatment involves physics, chemistry, bacteriology and biochemistry.

Sewage Treatment may be classified as Primary and Secondary.

Primary Treatment is one in which untreated sewage is the influent. It is largely mechanical in nature depending on screening and settling.

Secondary Treatment usually requires preliminary treatment of the influent and is largely biological in nature. Oxidation of organic matter is accomplished here.

The line cannot be drawn sharply between all primary and secondary processes.

Primary processes are comparatively simple in their equipment and operation, are less expensive in first cost and operation. The effluent is of a lower standard quality.

In sewage treatment, it is impossible to destroy any of the elements present.

They can be removed from the mixture only by gasification, straining or sedimentation. Chemical combinations may be so changed, however, as to result in different substances from those in the raw sewage.

SEWAGE TREATMENT AND DISPOSAL PROCESSES:

1. Disposal without Treatment or after Treatment -

   A. Dilution or disposal into water.

   B. Irrigation or disposal on land.

2. Methods of Treatment -

   A. Coarse Racks

   B. Fine Screens

   C. Comminution (grinding) of coarse solids from racks and screens

   D. Skimming

   E. Sedimentation

      Grit or detritus removal.
      Settable solids removal.

   F. Sedimentation with chemical precipitation.

      Settleable solids and some colloidal and dissolved solids removed.
      Patented chemical processes.

   G. Septicization

      Septic Tanks
      Imhoff Tanks

   H. Filtration

      Contact Beds)
      Trickling Filters - Standard Rate)
      Trickling Filters - High Rate)
      Intermittent Sand Filters)
) Oxidation
   I. Activated sludge process with its) Methods.
      many modifications.)

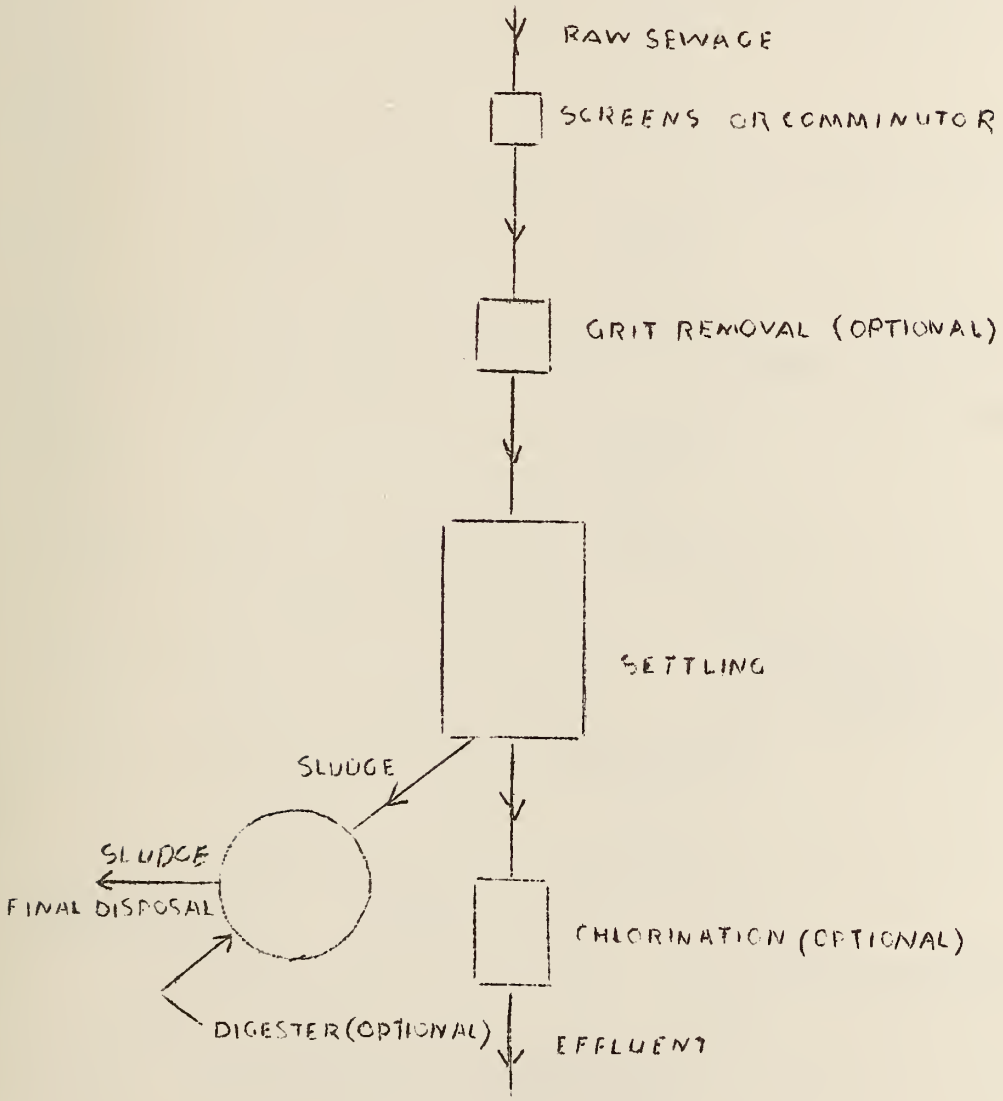
J. Sludge Treatment

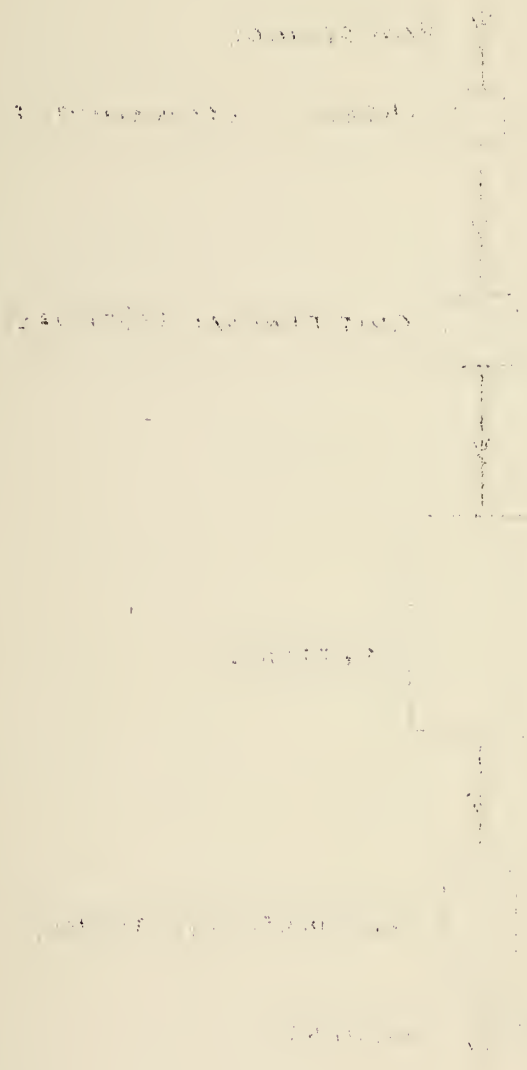
Digestion
Disposal into water or onto land

K. Sludge Drying

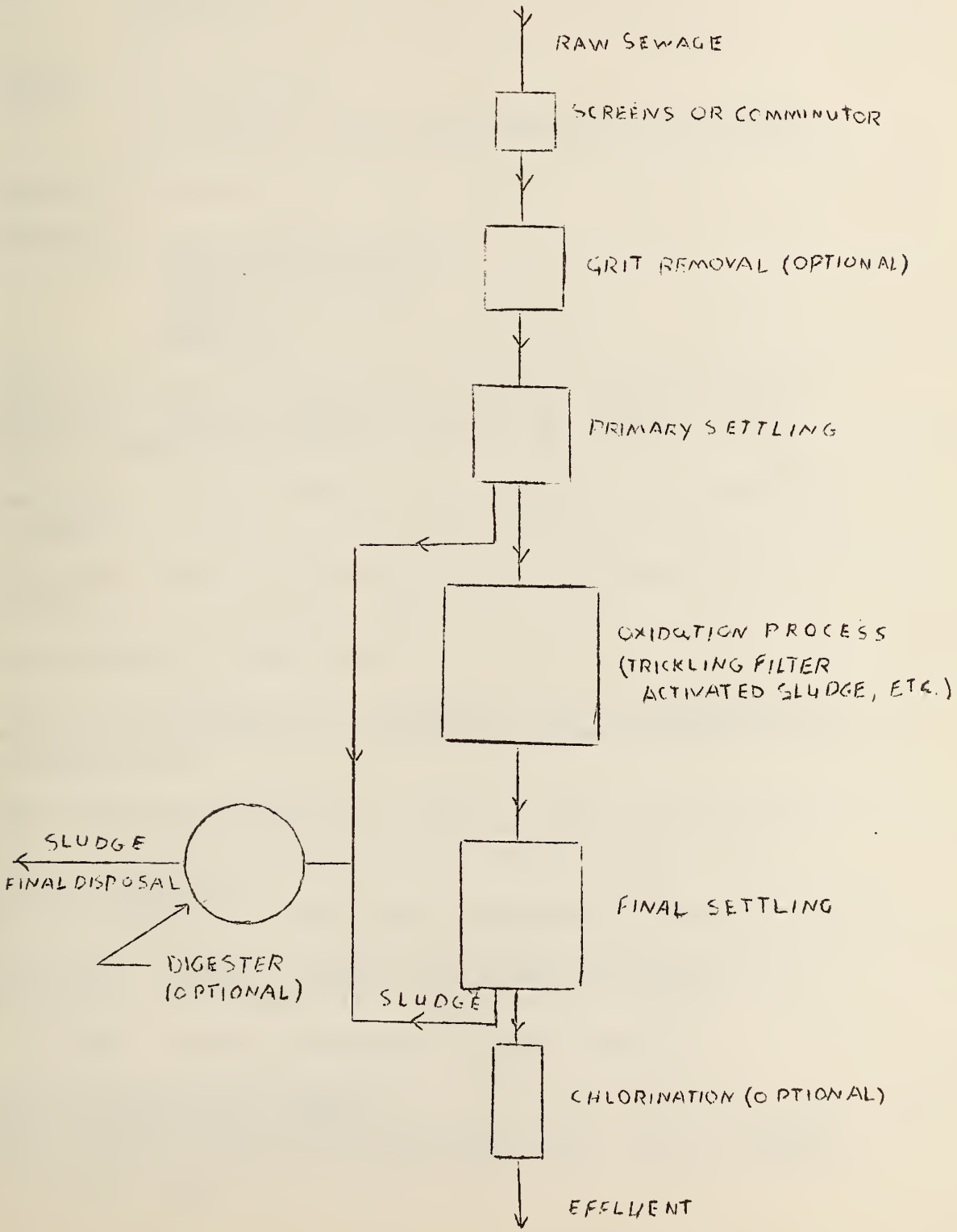
Sand Beds
Presses
Centrifuges
Vaccuum Filters
Elutriation
Heat Dryers
Incineration

LINE DIAGRAM OF A TYPICAL PRIMARY TREATMENT PLANT





LINE DIAGRAM OF A TYPICAL SECONDARY TREATMENT PLANT



ANALYSIS OF SEWAGE:

Complete analysis of sewage, called a Sanitary Analysis.

Some of the tests carried out are -

Solids - Total
Suspended
Dissolved

Oxygen - Dissolved O_2
O_2 Consumed
O_2 Demand - B.O.D. Biochemical Oxygen Demand.

Relative Stability -

Nitrogen - Free ammonia
Albuminiod ammonia
Organic nitrogen
Nitrites
Nitrates

Chlorides, fats, alkalinity, acidity, bacteriological analyses etc. Routine analyses consist of solids, B.O.D. and bacteriological analyses.

Suspended Solids - Those in suspension - taken out on a filter paper.

Dissolved Solids - Those in solution - taken out by evaporation.

Total Solids - sum of two.

B.O.D. of polluted water, sewage or other substance is the amount of O_2 required to maintain aerobic conditions during decomposition.

Most analyses reported in p.p.m. - parts per million.

Bacteriological - reported in M.P.N. per 100 c.c. - most probable number.
Average raw sewage has 250 p.p.m. suspended solids and B.O.D.

Sampling - usually sample raw sewage and effluent in sewage plants. Sometimes take intermediate samples.

Composite samples preferable to grab samples.

TREATMENT OF SEWAGE IN DETAIL:
Dilution feasible only where there are large bodies of water and water works intakes, bathing beaches etc. are of sufficient distance away.

Some dilution is necessary even with treated effluents. Trouble is experienced in some places with insufficient or no diluting waters.

The diluting water supplies O_2 to the sewage and prevents septicity.

In Ontario - do not consider the dilution of raw sewage as satisfactory. Require some degree of treatment. Degree depends on local conditions.

Factors to be Considered Under Dilution -

1. Floating substances may create offensive conditions to the eye.

2. Sedimentation may take place in the diluting water forming sludge banks.

3. An O_2 balance must be maintained to prevent septic or offensive conditions, i.e. there must be enough diluting water.

4. There may be contamination of water supplies, beaches, fish, recreational areas, ice supplies and agricultural land.

Broad Irrigation - An early European practice of disposing of sewage in open trenches. Not feasible in Canada due to cold winters.
Once used at Kitchener.

Obsolete.

Modern versions are lagooning for domestic sewage and spray irrigation for milk and cannery wastes.

Lagooning - successful out West. None in Ontario yet. Camp Ipperwash and Wasaga Beach are likely prospects. Good for fluctuating populations. Lagoon must be isolated.

No sedimentation required. Basis of design, about 10 acres of lagoon per 1000 population. Liquid evaporates or percolates into soil. Are experimenting with 90 day lagoons that have an effluent.

SCREENING:

Coarse Screens - every sewage plant has coarse bar screens (or Comminutors) to remove large solids, sticks, stones, rags etc. which might injure machinery or hinder the processes.

Small plants - hand cleaned. ¼" x 1½" bars @ 2" centres 30-60° to horizontal.

Large plants - mechanically cleaned.

Sometimes screenings are ground and returned to the sewage, either float or time controlled.

Disposal of Screenings - burned, buried, digested or ground and returned.

Comminutors - are mechanical grinders which grind these solids automatically without the use of screens.

Fine Screens - remove more material from the sewage. Often put in plants that have heavy industrial wastes (Cobourg and Kitchener) to reduce the load on the treatment processes.

Some municipalities have fine screening as their only method of treatment - Sudbury and Hamilton. Is more expensive than sedimentation.

Also used for industrial waste treatment - tanneries, canning factories, abattoirs, etc.

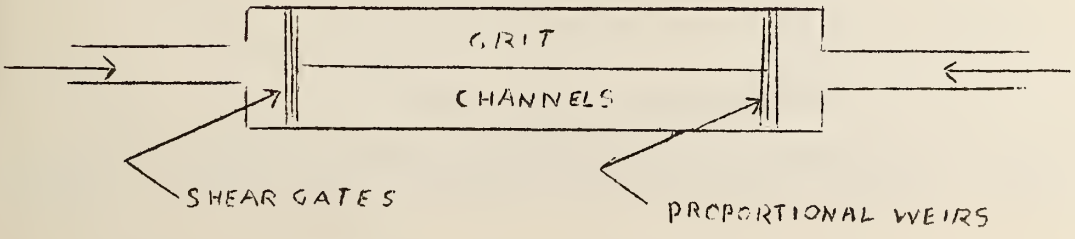
Usually are drum screens, disc screens or vibrating screens. Efficiencies vary with the mesh. Maximum removal in ordinary sewage is about 10% - 15% of the suspended solids.

Fine screenings are usually incinerated or buried.

Grit Removal - Grit removal facilities are desirable in every treatment plant.

Remove the grit, sand and other inorganic material which may injure machinery or hinder sludge digestion.

Usually accomplished by sedimentation in plain tanks. They are shallow - 2-3 ft. deep, narrow - 3' wide, length - 30-60 ft. Retention - ½-1 minute.



Theory is to reduce the velocity of the sewage to about 1 ft./second. This is slow enough to let the heavier inorganic matter settle out, but it is not slow enough for the organic material to settle.

Small chambers are cleaned manually. Larger ones mechanically.

Some mechanically cleaned tanks have grit washers.

Recent innovation is removal of grit by diffused air.

Sedimentation -

Widely used in sewage treatment. The purpose is to settle out the solids from the liquid by gravity.

A number of different kinds of tanks are used. The settled sludge may be removed manually or mechanically.

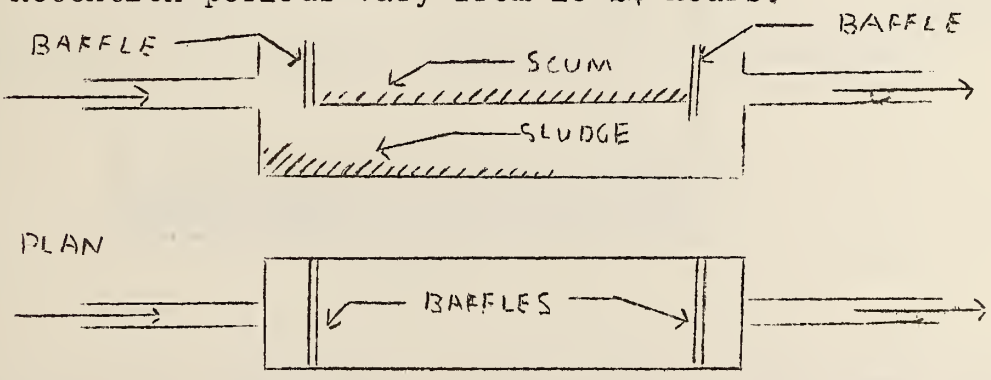
1. Plain, Single Story Tanks:

It was the earliest design - called the septic tank. The effluent lacks O_2 or is said to be septic.

In this tank the sludge is in contact with the incoming raw sewage and this tends to make the settled sewage more difficult for secondary treatment.

The tanks are usually rectangular and longer than wide. The length should be 2-3 times the width to prevent short circuiting.

Retention periods vary from 10-24 hours.

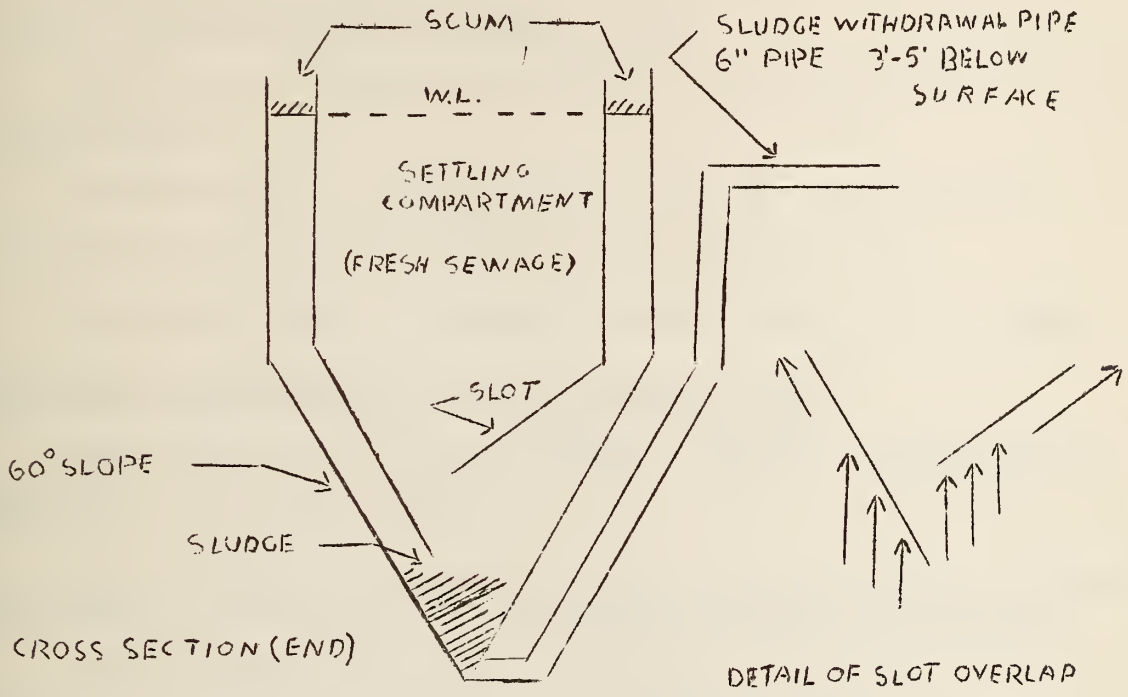


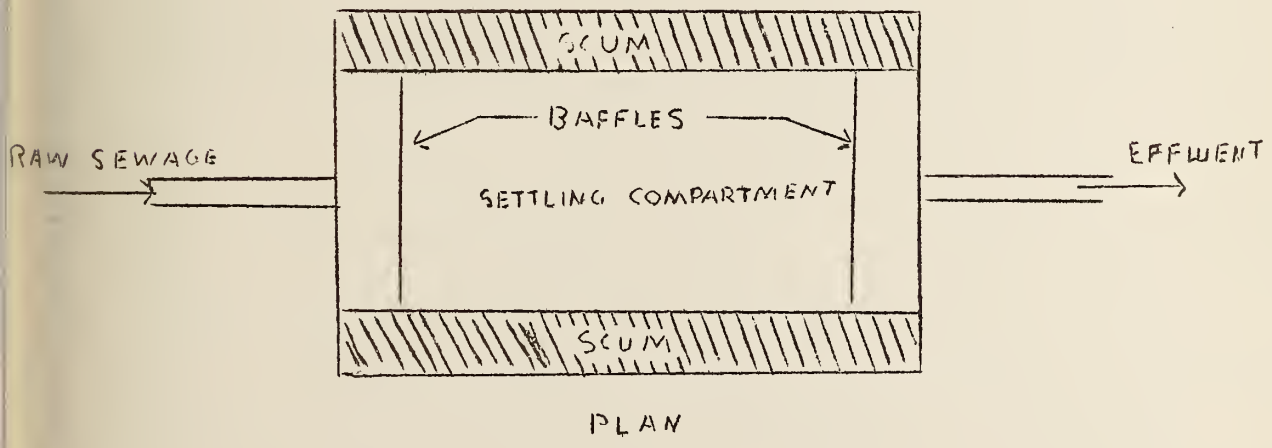
The sludge in this tank is removed probably 2 or 3 times a year. It runs out through ports in the bottom or may be pumped out from the top.

2. Two-Story Tanks - Imhoff Tanks:

Developed by Dr. Karl Imhoff in Germany.

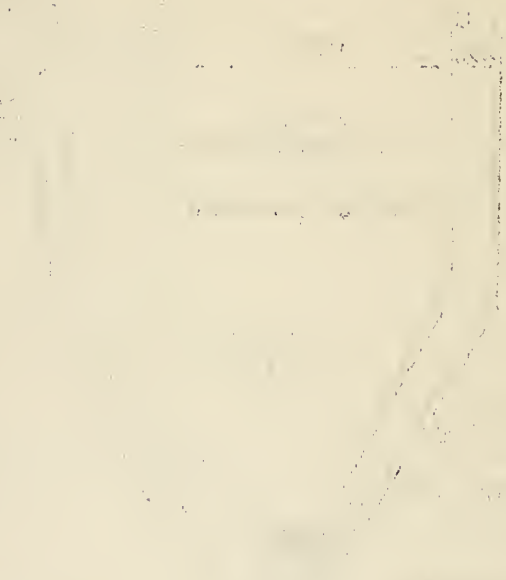
Purpose was to separate the raw sewage from the digesting sludge and thus improve the quality of the effluent for secondary treatment (not septic).

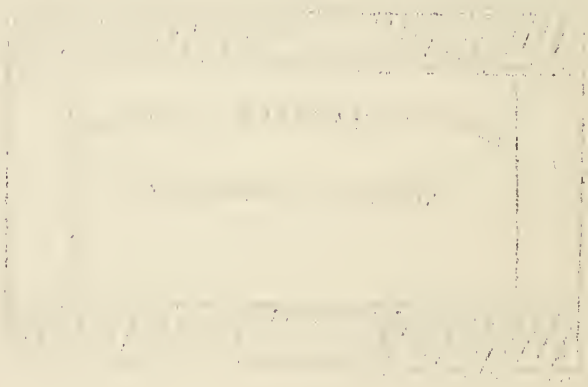




There is only fresh sewage in the settling compartment and there should be no scum on the surface. Retention periods vary from 1½ to 4 hours depending on the type of additional treatment.

The sludge compartment is big enough to hold the sludge





for about 6 months. This works out to about 6 cu. ft. per capita.

The sludge digests and when drawn off, it is black in colour and relatively free from odour.

The sludge is withdrawn through a pipe while the tank is in operation.

Disadvantage is the expensive cost of construction.

Difficult formwork and excessive depth - 30'.

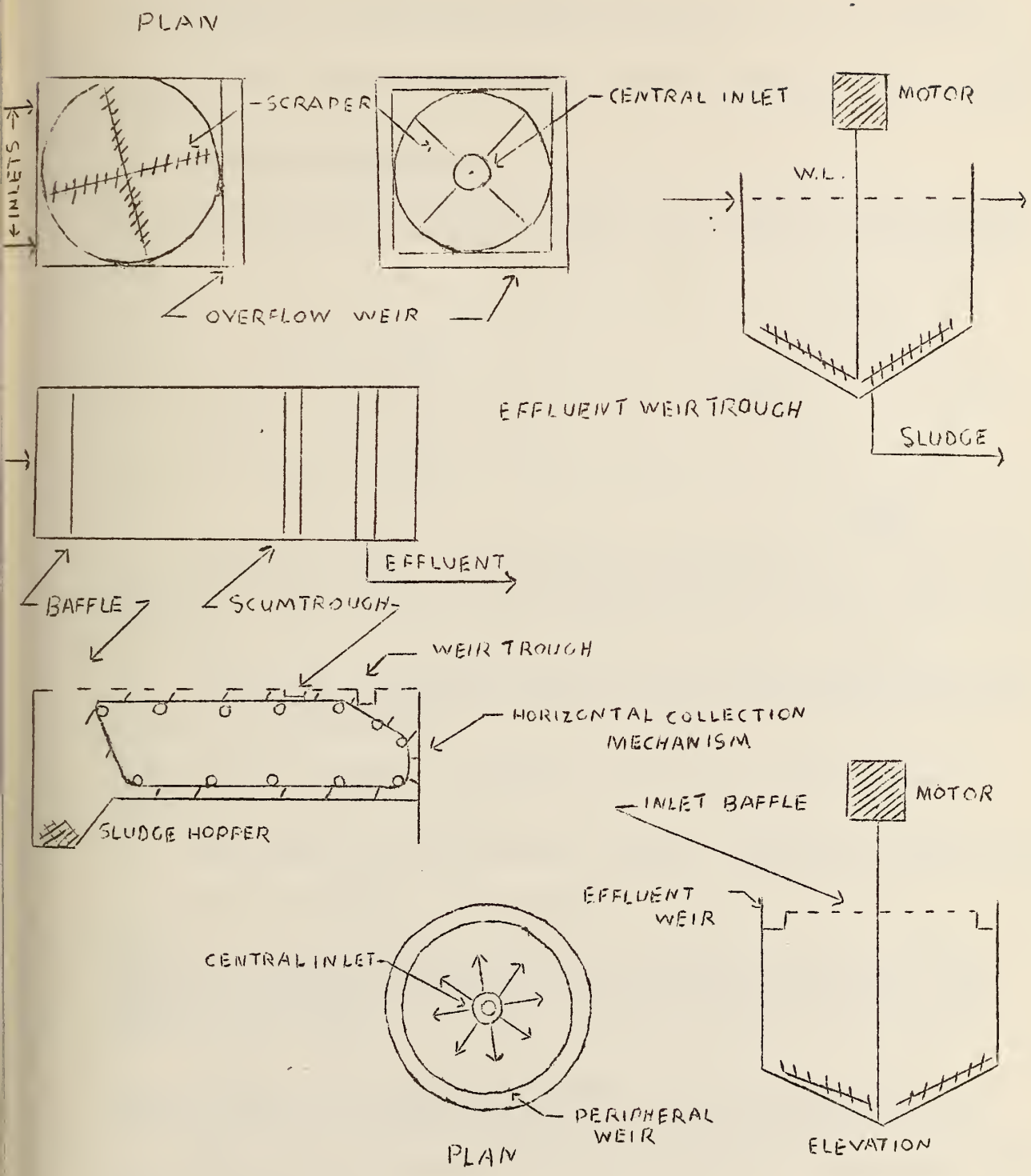
Few built today - favouring mechanically cleaned tanks.

3. Single Story - Mechanically Cleaned Tanks:

These may be of various shapes - square, rectangular or circular. Bottom is almost flat with only a slight slope to the centre or sludge outlet.

The mechanical equipment consists of motor-driven scrapers operating on the bottom to remove the sludge continuously.

Flow-through tanks have side inlets and outlets while others have central inlets and peripheral weirs.



Long lengths of weirs - low outlet velocities.

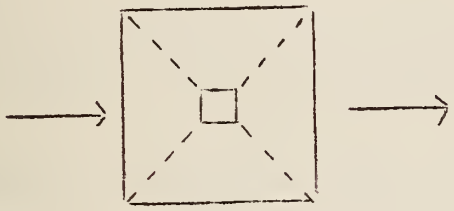
Retention periods vary from 1½ to 3 hours depending on use of tank.

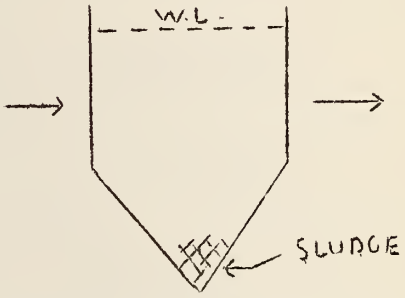
Details of tanks and equipment vary with the manufacturers, but the principles are the same.

Modern sewage plant design favours mechanically cleaned tanks.

3. Hopper-Bottom Tanks:

Formerly used extensively for all sizes of tanks. Now confined mostly to units too small for mechanical cleaning.





In these tanks, the sides of the hopper is so built that settled sludge slides to the bottom of the hopper where it is removed.

Trouble is encountered when these sides deteriorate and the sludge does not slide. The sludge then decomposes and rises to the surface.

Efficiencies - Based on removal of B.O.D. and suspended solids.

Suspended solids removal - 50-75%. Average is about 60%.

B.O.D. removal - about 35%.

Chemical Precipitation - This is a sedimentation process using a coagulant to improve the settling efficiency. The chemicals employed are alum, ferric chloride, ferrous sulphate, lime, etc.

Dosages vary with the sewage. Process consists of a mixing period of 30-60 minutes followed by sedimentation.

Efficiencies are about 80-90% removal of suspended solids and 50-55% B.O.D.

Process is not popular in this country due to high cost of chemicals.

Intermittent Sand Filter - is a filter acting somewhat similar to a water filter.

The filter is made up of sand and is dosed intermittently with settled sewage, i.e. it must be preceded by sedimentation.

Best operation is obtained with 4 beds in rotation, each bed being used for one day and rested for 3. The beds are usually dosed with a syphon.

Effluent is good with 90-98% removal of suspended solids and B.O.D.

In many places, these beds are improperly used by operating the beds near or to refusal before rotating.

The actions taking place are both straining and some oxidation by entrained air. This type of treatment has been used in a number of small municipalities in Ontario.

It is also well suited for small temporary plants where more treatment is required than plain sedimentation.

A number of these filters have been used as effluent or polishing filters on activated sludge and trickling filter plants.

The rate of filtration is low - 75,000-150,000 gals./acre/day or 600-700 persons/acre.

Effluent filters may be operated up to 750,000 gals./acre/day.

Contact Filters - Is a filter bed of 2" - 3" Ø stone in which settled sewage is held for 1-4 hours. It is an oxidation process in which a film of bacteria forms on the stone and oxidizes the sewage.

The process is now obsolete, being replaced by the trickling filter.

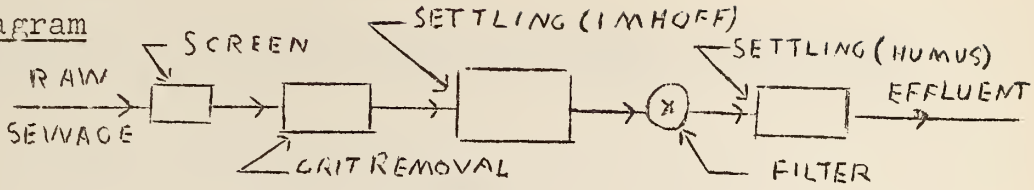
Trickling or Sprinkling Filters - A method of secondary treatment of sewage developed years ago, which is still used today with various modifications and improvements.

It consists of a filter bed of stone or other material on which the settled sewage is sprinkled by various methods. The process is similar to the contact filter where a film of oxidizing bacteria oxidize the sewage.

Rate of filtration through the bed - 1-2 m.g./acre/day. Depth of bed about 6 feet.

Efficiency - about 80-85% removal of B.O.D. and solids

Flow Diagram



Filter Media - The most common media used today is crushed rock. Specifications call for this stone to be about $2\frac{1}{2}$ to 4". Other materials that have been used are coal, coke brushwood (bound together) or any similar material on which a film may form.

The film is made up of oxidizing or nitrifying bacteria which feed on the organic material in the sewage.

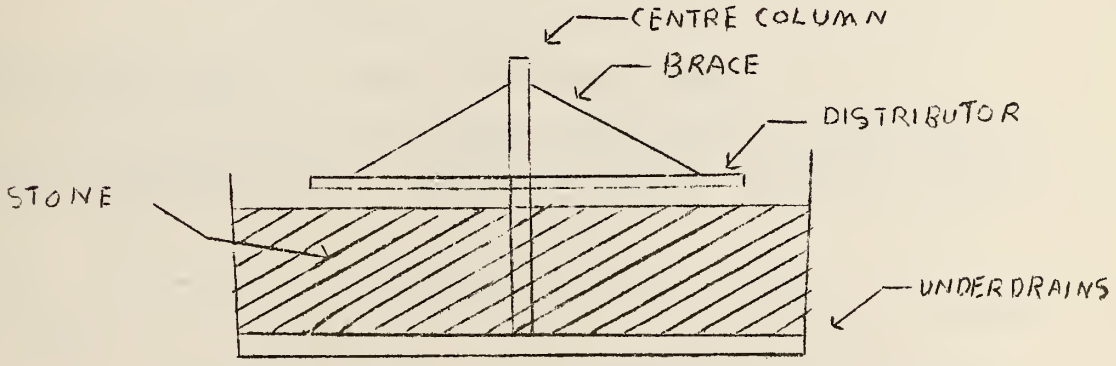
Oxygen from the atmosphere is passed down through the bed to supply O_2 to these bacteria.

No solids are retained on the filter but they are merely changed or coagulated so they can be settled out.

Periodically when the growth on the filter becomes too heavy, some breaks away and is collected in the final tank. Filter is said to sluff off.

Usually occurs in spring and fall.

Primary settling in earlier tanks was in Imhoff Tanks.



Underdrains - various types in use. The most common is specially constructed tile which supports the stone and allows the liquid to be carried off.

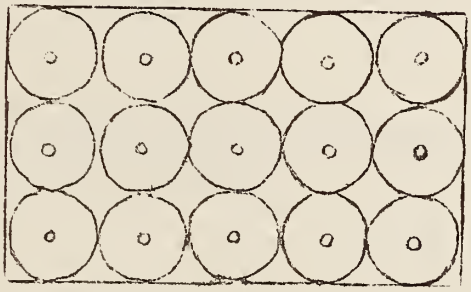
The openings must be large_____ at least 1".

Distribution of sewage on the filter:

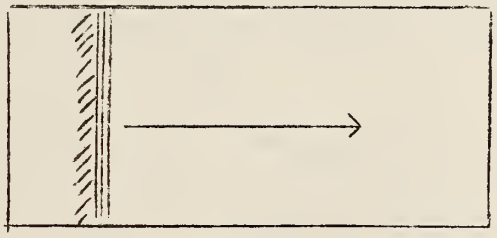
It is applied to the filter intermittently, usually by a dosing syphon following initial settling. Applied about once a hour.

3 methods used to distribute sewage.

1. Fixed Nozzles - so arranged as to sprinkle all parts of the bed. Practically obsolete. London, Burlington.

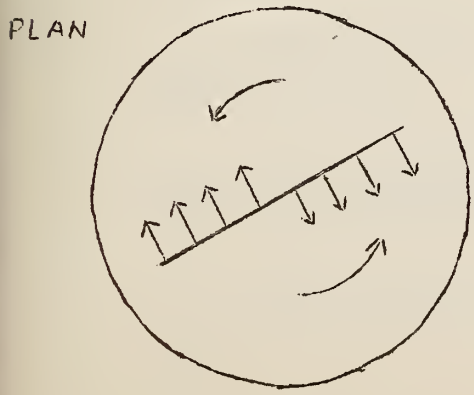


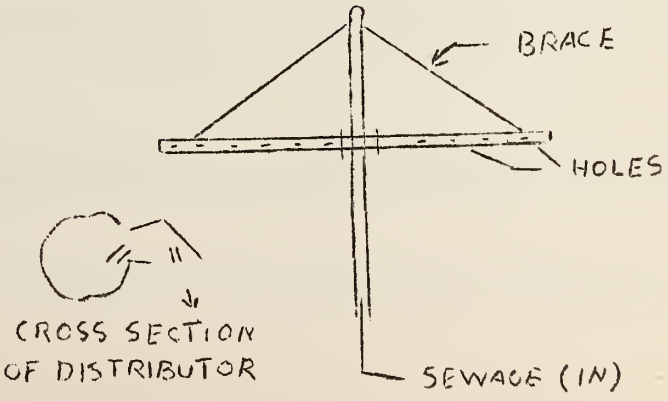
2. Travelling Distributor - moves back and forth on a rectangular bed. Operated hydraulically, also obsolete.



3. Hotary Distributor - Used universally now.

It is revolving distributor similar to a large lawn sprinkler operated by water pressure. Various designs depending on the manufacturer.





Humus or Final Settling Tank:

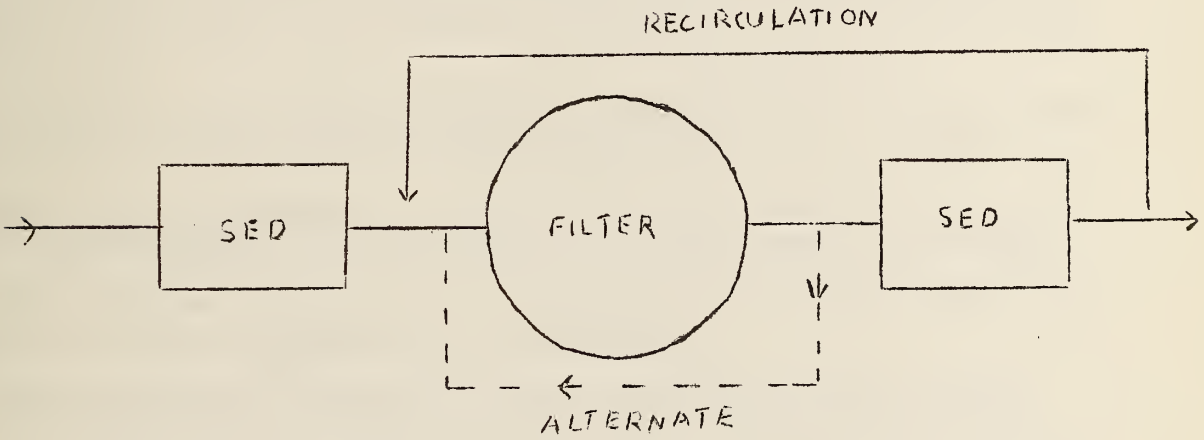
This gives sedimentation to the effluent from the filter and collects the solids which have been oxidized or coagulated by the filter.

The humus tank is any kind of sedimentation tank. Retention period is 1-2 hours. This period was much shorter in older plants.

High Rate Trickling Filter:

A recent development in the use of trickling filters. Very popular in the U.S. and a number of plants here - about 20 in Ontario.

In this version, the sewage is recirculated back through the filter and mixes with the incoming sewage. The rate of recirculation to raw sewage is usually 1:1.



TYPICAL FLOW DIAGRAM

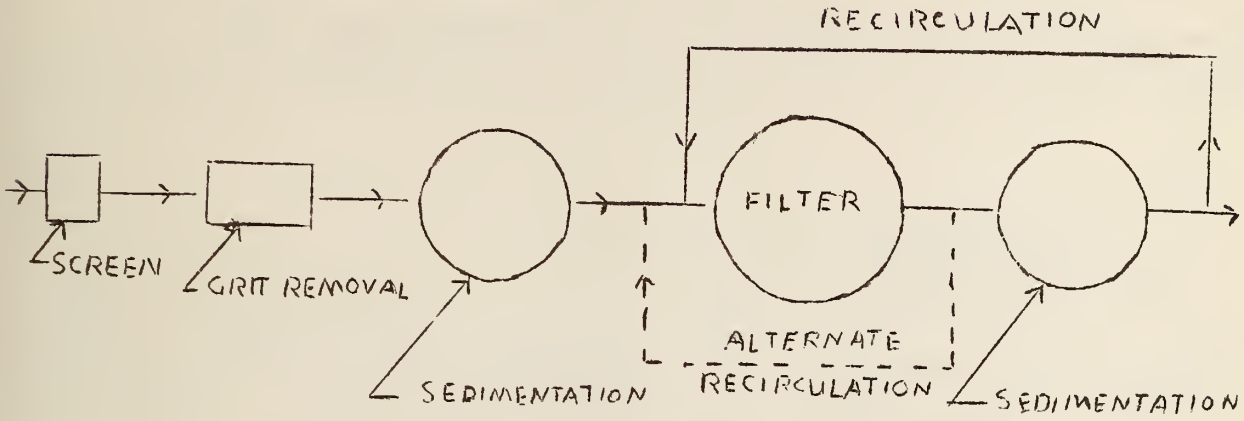
The methods and points of recirculation vary with designs and equipment. Some plants have two or more filters in series and dual recirculation.

Recirculation gives additional biological treatment, and is especially useful for strong wastes such as milk plants, tanneries etc.

Rate of filtration, 10-30 MG/acre/day, is much higher than in the standard filter and the dosing may be continuous. Hence the units are smaller.

Specifications on stone are the same as for standard rate.

This improves the efficiency to about 90-95% removal of suspended solids and B.O.D.



A number of these plants have not been too successful in Ontario - probably due to faulty design (hydraulics) and poor filter stone.

Sedimentation tanks are usually mechanically cleaned and recirculation is by float-controlled pumps.

Activated Sludge Process - A biological process involving the use of compressed air with sludge on solids from the sewage.

The sludge is said to be activated and besides oxidizing organic matter, also acts as a coagulent.

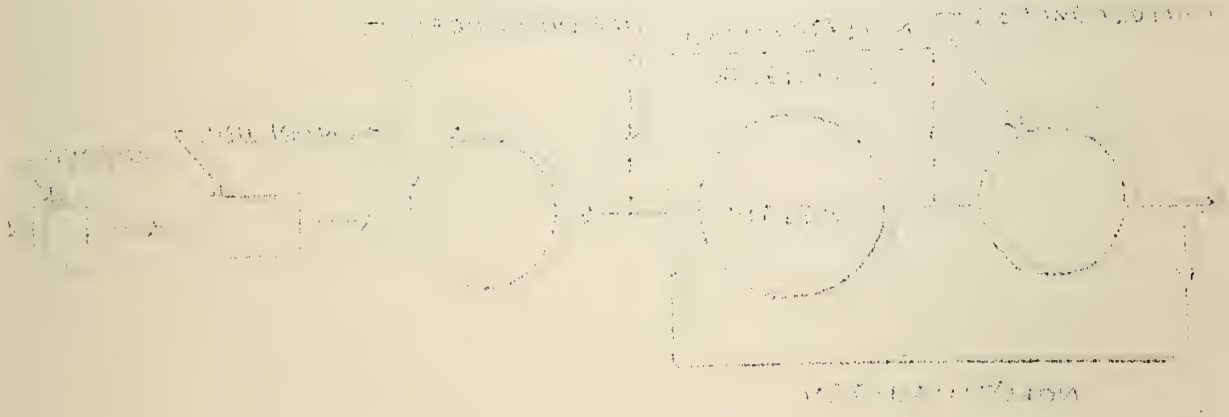
The process is similar to the trickling filter except the film that formed on the stones moves about in the sewage.

The early tests used trickling filter film, and when it was mixed with sewage and air, a rapid treatment of sewage resulted.

Sewage, after some preliminary treatment to remove some suspended solids, usually sedimentation, is mixed with activated sludge to form a mixed liquor.

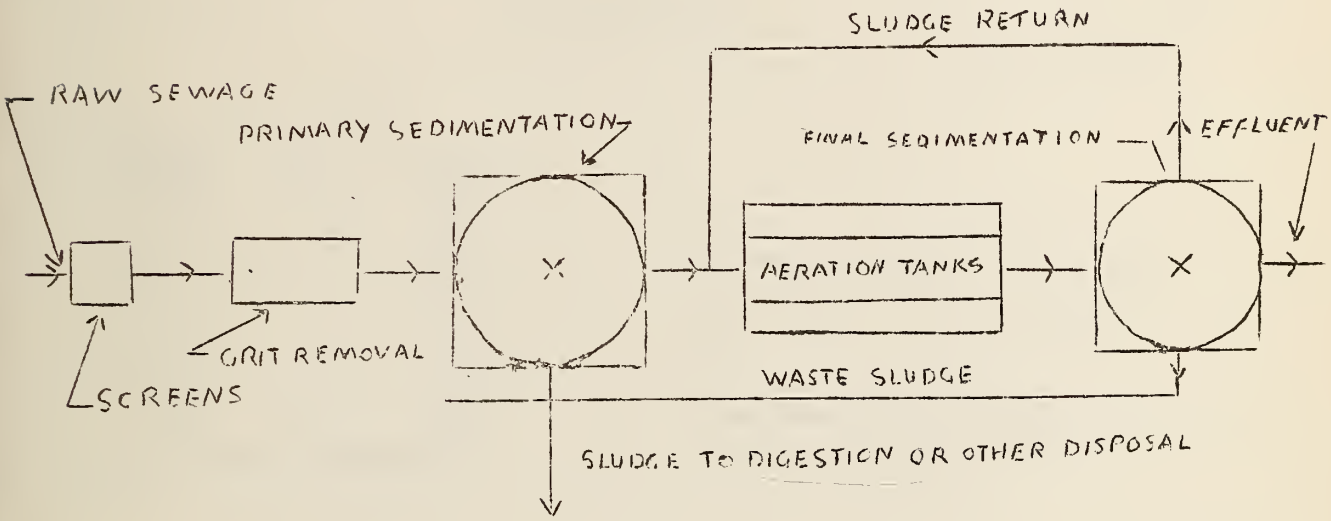
The mixed liquor passes to an aeration tank where it is subjected to prolonged aeration.

The aerated mixed liquor then passes to a final tank where the clear supernatant is drawn off as the effluent.



Part of the settled sludge is returned to the aeration tanks as returned sludge to form the mixed liquor with the excess going to sludge disposal.

The exact theory of the Activated Sludge Process is not fully understood, and even today there is some disagreement.



FLOW DIAGRAM

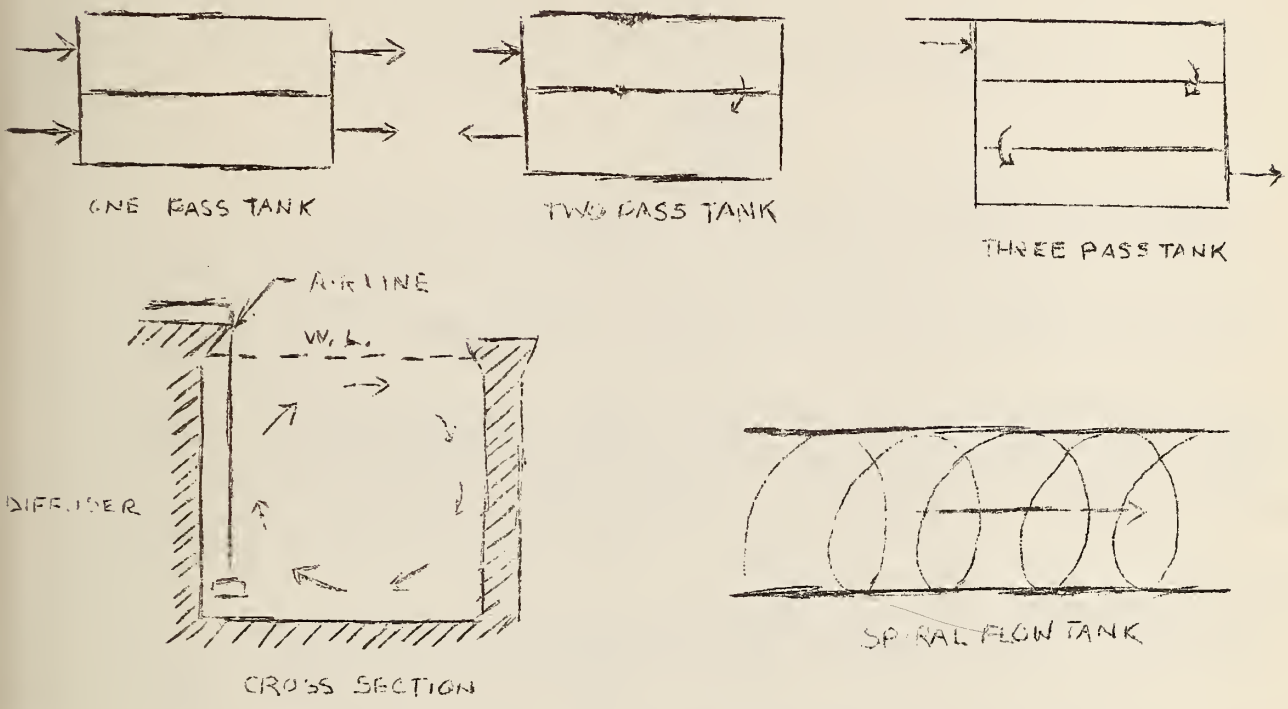
Primary Sedimentation - Retention period 1-2 hours

Any kind of sedimentation tank may be used. Usually mechanically cleaned. Was omitted in older plants.

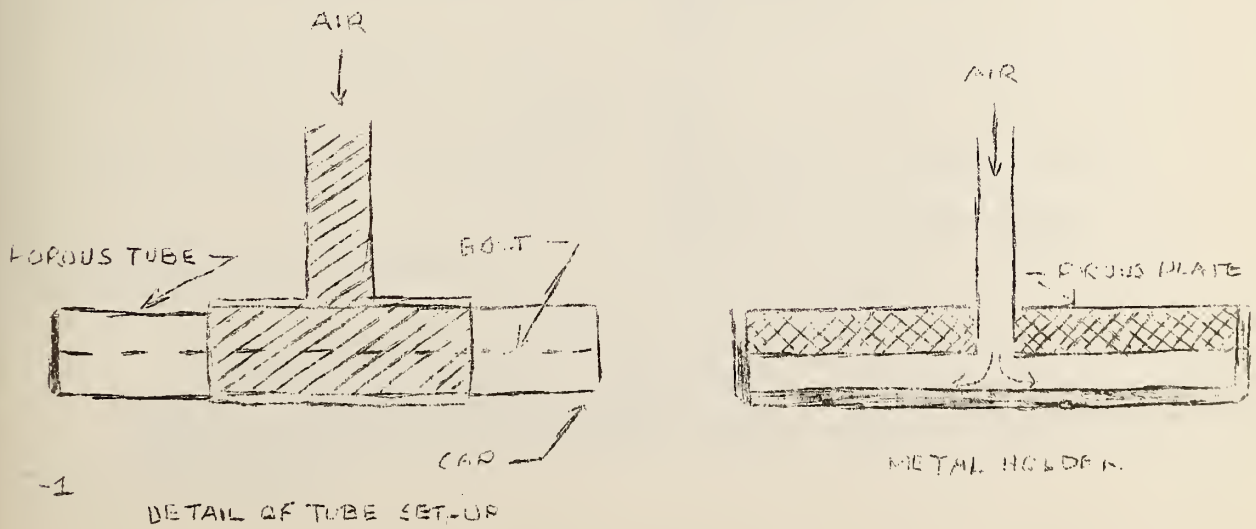
Aeration Tanks - Contains settled sewage and activated sludge and is agitated by air blown in at the bottom. The tanks are about 10' wide and about 10' deep. The length is variable up to about 300 feet.

Retention period is 6 hours of a mixture of settled sewage plus 25% returned sludge.

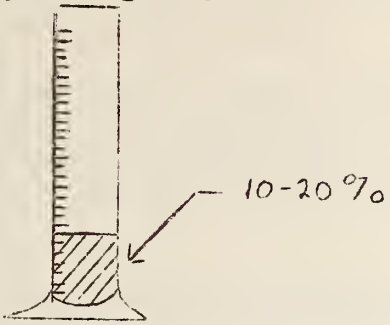
The aeration tanks are arranged in various manners.



Air is supplied by compressors or blowers and is introduced to the sewage through porous tubes or plates. Another type of tube is wrapped with Saran Cord.



The amount of sludge in the aeration tanks should be from 10-20% and is determined by doing a ½ hour settling test.



The sludge is returned at a rate to give this figure. When this amount is exceeded, the surplus sludge is run off.

Amount of Air Required - about 1 cu. ft. per gal. of sewage. The pressure is about 6-8 p.s.i.

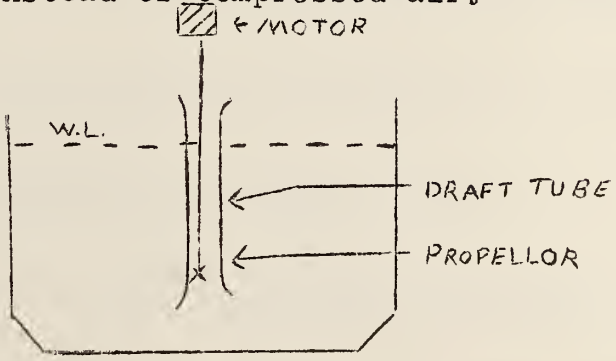
Final Settling Tank - This takes the mixed liquor from the aeration tanks and settles out the solids. The clear liquor or effluent goes to the outfall. The settled sludge is returned by air lift or pumps to the first part of the aeration tanks.

When there is too much sludge, some of it is run off to final disposal or is wasted to the primary tank. This is done usually for 1-2 hours a day.

The final tank is usually mechanically cleaned but the older units may have hopper bottoms.

The sludge must be returned continuously or it will turn septic and lose its oxidizing powers.

Mechanical Aeration - Some plants use mechanical means to aerate the sewage instead of compressed air.

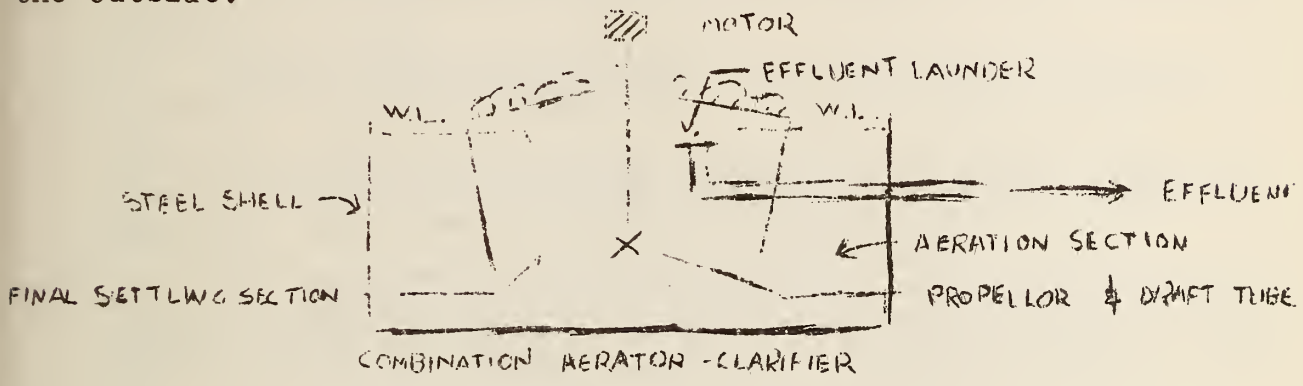


MECHANICAL AERATION

The mixed liquor is pulled up through a draft tube in the centre of the tank by a motor-driven propellor and splashed over a specially constructed plate. O_2 is obtained from the atmosphere.

Due to the slower rate of obtaining the O_2 aeration periods must be longer - 8-11 hours. The rest of the plant is the same as for conventional acticated sludge.

Combination Aerator Clarifier - Some of the small mechanical aeration plants have combination aerator clarifiers. This is a tank with the final settling compartment enclosed in a steel shell in the centre with the aeration section around the outside.



These plants are preceded by primary settling and are similar to conventional plants in all other aspects. They are commonly referred to as "Package Plants".

Chlorination of Sewage - Cl_2 is added to sewage for one or more of the following purposes.

1. Disinfection of effluent - a contact chamber of 15-20 minutes is necessary 5.-10 p.p.m. of Cl_2 usually is necessary to produce a .5 p.p.m. residual.

2. Control of odours - added to the raw sewage or at a number of points in the plant to control odours.

3. Reduction in B.O.D. - Cl_2 is a strong oxidizing agent and will reduce the B.O.D. by oxidizing organic matter. Of secondary importance.

4. Removal of Grease - Cl_2 combined with aeration is effective in removing grease by flotation.

5. Improvement in Sedimentation - Cl_2 has the property of improving settling especially in final tanks.

Sludge Disposal - In raw state, sludge is highly offensive as it decomposes. In addition, it has a high water content - 90-99% hence is a large volume.

Except in special circumstances, sludge is given some further treatment before final disposal.

Treatment of sludge is necessary to control odours and reduce the volume.

Treatment for Control of Odours:

1. Digestion or decomposition.
2. Incineration
3. Plowing into the soil.

Digestion - may take place in the bottom of a septic tank in the sludge compartment of an Imhoff Tank, or in separate digestion tanks.

Modern plants with mechanical sludge removal utilize separate digestion tanks.

The tanks are air-tight, and heat is usually added to keep temperature at 85-90°F. Heating hastens the digestion process, hence smaller digesters are required.

The gas given off (largely methane) is collected at the top. It has a high heating value and in the larger plants is used to heat the tanks. The surplus gas may be used to heat the buildings or may be burned in a waste gas burner.

Amount of gas produced is about 1-3 cu. ft./capita per day. Ground garbage in the sludge would increase the gas production.

The period of digestion is about 6 weeks to 2 months for heated digesters, longer for unheated units. Fresh sludge is added daily.

The final product, heated sludge, is black in colour, free from odour (earthy) and will dry readily.

Heated digester capacity required varies with the treatment process varying from 1-2 cu. ft./capita for primary treatment to 6-8 cu. ft./capita for activated sludge.

Digestion reduces sludge volume by about 40-50%.

Incineration - This is a burning at a high temperature-1400°F. and up to destroy organic material leaving only an ash residue (about 10% of original).

Carried out in specially constructed furnaces Handles raw or digested sludge, as well as screenings. No extra fuel is required.

Only feasible for large or moderate size plants.

In Ontario only Toronto, main plant at Ashbridges' Bay, uses incineration.

Plowing into Land used for small amounts. Still offensive if the sludge is raw.

Should be some distance away from residences.

May be transported in liquid form or after mechanical dewatering.

Methods for Dewatering Sludge -

1. Sand Beds for drying (open or covered).
2. Vacuum Filters.
3. Centrifuging

Sand Beds - Constructed with about 12 to 18" of fine sand with underdrains. Most of the moisture evaporates. Many earlier sand beds were glass covered like greenhouses to keep out rain and control temperatures

Covered beds are now considered too expensive to build and maintain and none have been constructed in Ontario for some years.

Size of bed is governed by condition of sludge. For digested sludge, 1-2 sq. ft./capita, larger beds for raw sludge.

Sludge is run onto beds in 10" layers and dries in about 2 weeks of good weather.

Sludge beds are not feasible for large plants.

Vacuum Filters. - This type of filter exerts a partial vacuum on the sludge pulling the water in the sludge through a cloth blanket. The now semi-solid sludge can be scraped off the cloth as the drum revolves.

Will handle raw or digested sludge. A coagulent, usually ferric chloride, is used.

Centrifuges - Same principal as a cream separator. A few used in the U.S., none here. Not too successful.

Liquid sludge is not to be used on market vegetables unless spread on the land the previous Fall.

May prove to be a problem to local Health Officials.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: SEWER SYSTEMS-OPERATION AND MAINTENANCE

Instructor: E. E. W. Oke

Design of sewerage system

We will not go into detail as I know you are not interested.

The design of sewers does however affect the operation of the treating plant and it will be from this view point that we will consider this phase.

There are several factors that must be considered in the design of a sewer:

Flow

The total flow is readily determinable. It is generally based on the water consumption of the municipality in question which may range from 80 to 120 gpd per capita.

With the population of the area to be served known or calculated, the flow from this area is then readily obtained. To this must be added the flow from other sources such as industry, etc. and infiltration. The amount of infiltration is dependent on the type of soil through which the sewer is to be laid and the type of jointing used.

You will note that the flow is based on a 24 hour period. The size of sewer must be large enough to carry the maximum flow over a very short period, so that the Rate of Flow in cfs is the determining feature.

Another factor that must be considered is the amount of storm water that the sewer will be required to handle.

There are two generally accepted systems of sewerage- "Separate" and "Combined". In the "Separate" system, the sanitary sewer theoretically is only required to carry sanitary flow, but in practice some storm water must be expected as in spite of all efforts to prevent it, some rain water will get into the sewer. Roof water drains will be connected to the sanitary sewer in spite of all you can do to prevent it. The storm requirements are vastly in excess of sanitary requirements so that a small amount of storm connections upsets completely the theoretical size of sewer based on sanitary only. As a matter of fact, in a

in a combined system the storm flow almost entirely determines the size of sewer required.

The rate of flow is therefore the total flow in cu. ft. per 24 hours reduced to seconds and multiplied by a factor to obtain the Rate.

The factor used is 2 or 3 as experience dictates. The proper factor to use is dependent on the number of buildings being served. At the upstream end, the factor must be larger than at the lower end and progressively diminishes from one end of the system to the other, but not uniformally.

This does not sound very scientific and frankly it is not. The success of the sewer, however, depends on a correct determination of flow and therefore hinges largely on experience. To overcome this weakness, we have developed a method for determining the correct factor. The graph is purely theoretical but appears to work. The factors range from 4 to 1.35.

Slope Ratio (Grade)

The next factor that must be considered is "Slope Ratio" (fall in feet per lin. feet of route). This factor is largely controlled by the terrain and can only be adjusted within narrow limits. This factor helps to determine the size of the pipe required to handle the flow.

Velocity of flow must be controlled within certain limits. Too low a velocity permits the solids to settle out in the sewers, blocking them and when flushed out with a large flow, these solids which have been lying in the sewer for some time will be septic when they reach the treating plant causing considerable trouble in the process. A certain amount of this septic sewage can be expected even with a properly designed sewer, because of the difference in the rates of flow. From midnight till morning, the flow is necessarily low and permits some settling and collection of sewage solids in the sewers. The subsequent increase in flow may or may not be sufficient and if some time elapses before they are flushed out, they become septic. Too high a velocity is also objectionable in that the rapid movement of sand particles in the sewage will wear through the pipe rapidly.

Type of Pipe

The type of pipe used must also be considered as each type offers different resistance to the flow. Manholes, also, may increase the resistance to flow. This is particularly true with change in direction of flow in the manhole.

With all factors determined, the size of pipe required is easily determined by use of the Manning Formula.

$$V = \frac{1.428x\ R.\ 2/3\ S\ 1/2}{n}$$

Where- V = Velocity
n = factor (for different pipe)
R = Hydraulic Radius (area of stream wetted perimeter)
S = Slope Ratio

In actual practice, a special slide-rule or Nomographs developed on this formula are used to facilitate the operation.

Operation and Maintenance

The operation of a sewerage system consists essentially of keeping the sewers in condition so that they function efficiently. This involves frequent cleaning and repairs, if and when necessary. Manholes serve two primary purposes, that of facilitating cleaning operations and providing for a change of direction of flow and/or inter-connections between lines.

Although manholes are costly, they must be located close enough to permit easy cleaning operations and at every change of direction and grade of the sewer.

The frequency of cleaning required is not the same for all sewers and many factors determine optimum time interval between cleanings. Generally, a flat sewer will require more frequent cleaning than a steep one, but the type of sewage and amount and type of foreign matter that the sewage carries, and the velocity of flow will largely determine the frequency of cleaning required. Past experience with a given sewer or section of sewer will be the best guide. Two main things must be guarded against:

blockage, and deposits of sewage solids long enough to become septic.

Introduction

The type of pipe wrench used can be considered as most open differential mechanisms do in that, the output [illegible] pressure on both [illegible] equally when in the middle.

[illegible] the pipe required to [illegible] for the [illegible]

$$\omega = \frac{[illegible]}{[illegible]}$$

ω = [illegible]
β = factor (for different pipe)
$\int$ = hydraulic loading (area of pressure plate)
τ = [illegible]

[illegible] pipe, a special slip-grip or [illegible] [illegible] of the forceps are used to facilitate the operation

[illegible]

The operation of a [illegible] pipe wrench requires [illegible] [illegible] the control by [illegible] [illegible] effectively. This involves [illegible] and regrips, [illegible] [illegible]. Jaw slippage may [illegible] [illegible] [illegible]

Flushing of sewers is a very common method, but our experience convinces us that it is very ineffective. It is dependent on the creation of a large flow of water with sufficient velocity to break up and carry with it all the solids that have settled. A fire hydrant with a 2 1/2" fire hose is usually used and it is obvious that a two and one half inch stream of water cannot supply the flow necessary in an 8" sewer or larger for this purpose. Another objection to this method is that it just carries the solids down to another section where the velocity is low enough for them to settle out again.

The most effective method of cleaning sewers is to remove the material outright from each section (from one manhole to the next) with the bucket method. This method consists of drawing a bucket (upstream) until filled, then drawing it back and emptying it. This operation is repeated until the bucket is drawn from one manhole to the next without collecting any solids. The problem usually presented in this method is the insertion of the cable from one manhole to the next to commence this operation. No one method will work under all conditions, and certain cases will require a combination of several methods.

The first and simplest is to float a line down from one manhole to the next and with it pull in a heavier line which in turn will pull the cable through. The success of this method of course depends on there being a sufficient flow to carry the floats through and that there is sufficient room for them to get through.

If the float-and-line fails, the sewer can be rodded and a line drawn back with the rods. If it is impossible to get the rods through which should never occur as it indicates that the cleaning operation has been neglected too long, a rotary nozzle on a 2 1/2" fire hose is used to clear out the sewer to permit the use of one of the other methods. The nozzle must be used up-stream. The revolving nozzle works very well in clearing a completely blocked sewer, but its use has one very serious objection. The material forming the blockage is washed down into the next section of sewer unless a trap is used to collett it and it is removed.

The operator's records can be very useful in the operation of the sewer system. Particularly is this true in the detection of abnormal leaks into the sewers that may give no physical evidence on the ground. An example may illustrate this. A cast iron sewer that crossed under a small artificial lake became exposed for a short section and for some unknown reason developed a break at the edge of the exposed section with the result that this line ran full for some considerable time before it was detected. The plant flow increased without any known reason which prompted the investigation that finally located the cause.

Maintenance and Repairs

Repairs are where you find them, and the type and method used in making repairs naturally depends on which needs repairing. Sewers are different to all other services. A section of a municipality cannot be notified that the service will be interrupted until a new section is laid or a break repaired. Service must be maintained even if the workmen work with sewage flowing through the trench. In a case of this kind, the plant will receive a great deal of soil mixed in the sewage which presents abnormal problems at the plant.

If a long section must be replaced, a sump may be constructed at the up-stream end of the section and the sewage pumped from this section to the down-stream section by-passing the section under repairs. The house connections originally served by the section under repairs naturally drain to the open trench, unless they too can be by-passed.

The following repairs, which correctly would be called replacements, present other difficulties. Where a sewer becomes too small to serve the increased demands on it, there are two general methods of solution:

(a) Lay the larger sewer along side of the old picking up the services as you go.

(b) A sump may be installed at the down-stream end of the good portion (generally a manhole) and the sewage by-passed by pumping. The house connections are transferred from the old to the new as they are reached.

The operator at the treating plant should be familiarized with any abnormal repairs or replacement so that he can anticipate conditions resulting from the work and will not be unduly alarmed by them.

Three abnormal experiences which we have had may interest the operator.

1. A section of sewer which was by-passed by another became blocked completely. The location was determined by rodding from the two adjacent manholes and opened up. Upon digging to the depth of the sewer it was not located. Then the trench was extended both ways until the two ends were reached and it was found that the sewer had settled and broken away at each end. The trench was then dug deeper to find the broken section, but it was never found. The trench bottom was built up to proper grade and a new section laid.

2. The paved roadway around a manhole at an intersection settled and when padding up the pavement it was found that the manhole had also settled. On investigation it was found that the floor and bottom of the manhole had disappeared which, to put it mildly, caused considerable concern. Further investigation brought to light the fact that one of our breweries periodically dumped concentrated sulphuric acid into this sewer and it had eaten away the bottoms of two manholes and the bulb of the concrete pipe in line for some considerable distance.

   Repairs were made to the manhole by digging down outside the manhole on one side at a time below the wall and floor of the manhole and repouring a new floor and walls.

   What is going to happen to the pipe line between manholes only time will tell.

3. A section of sewer about 600 feet in length into which a brewery discharges their bottle washings has frequently become blocked (solid). There is an alternate route for this sewage so that the blockage does not interrupt the service. The blockage material is a relatively hard greyish substance similar to a calcium scale. The first time the blockage occurred the men endeavoured to break through the blockage with the rods to insert the cable for cleaning. Failing to break through from the down stream side, a man went into the manhole above the blockage to prepare for rodding from the other side. He was only in the manhole a short time when he appeared to be in trouble and was told to come up by the foreman. Before he reached the top he succumbed and fell back. Another man went down to attach a rope to him for removal and he too succumbed. Both were removed but died a short time after. Tests made afterward showed oxygen deficiency and presence of carbon dioxide but the source of the carbon dioxide was not definitely traced.

   Since this unfortunate experience no men are permitted to descend into any manhole without a safety rope being attached to his person and another workman at the top to assist if required. A safety lamp must be suspended in the manhole at times when a workman is in the manhole.

   Recently while cleaning operations were being performed in this section the safety lamp was extinguished two or three times during operations. Samples of sewage fluid and solids were taken and analysed and the results have been interpreted as follows:

$$CaCl_2 + NaCO_3 + CO_2 \qquad CaCO_3 + 2NaCl + CO_2$$

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: SEWAGE PUMPS

Instructor: G. G. Reid

I have been requested to tell the class something of the underlying requirements and the average necessities encountered in operating sewage and sludge pumps. I have not been instructed concerning blowers but I think that any comprehensive talk on pumps would have to include airblowers because they are essentially the same in their operation, and airblowers are always present in every sewage plant in one form or another.

However, we will start with the most common form of sewage pump encountered in sewage plants - that of the Motor-Driven Turbine Pump for raw sewage. Now in most cases, raw sewage is either screened or goes through a comminutor before reaching the pump, but in spite of this, the pump must be designed in the impeller so that solids and debris will go through it without very much trouble. Consequently, the impeller of the pump should be an open type capable of passing at least a two inch sphere. Pumps are mostly ballbearing in modern days and the bearings will require grease cups or some other method of applying grease to them fairly constantly although not in great quantities. The design of every sewage pump should afford access to the impeller without removing the suction or discharge piping. In most cases, that means a split casing, but there are other makes of pumps that provide a hand hole so that you can get at the impeller without taking off the piping. Nearly all sewage pumps have stuffing box glands sealing the vacuum around the shaft next to the impeller so as to prevent leakage of air into the pump. Some of the most modern pumps have a double seal with a spring arrangement so as to keep the gland fairly snug at all times when the pump is running. These glands should either be kept under water pressure from a water source, or should be equipped with an automatic grease applier which is connected to the discharge of the pump so that when the pressure is on the discharge, there will be a corresponding pressure against the plunger of the pump which transfers the grease to the glands and keeps it under pressure at all times when the pump is running. This is probably the most important thing to see about in every sewage pump that is to see that the glands are kept under pressure in some way, either from water or from oil, or from grease or some source so that seal is present at all times and air cannot collect in the pump and cause excessive wear or even cause the

rings of the pump to burn out. This applies to vertical sewage pumps as well as to horizontal sewage pumps, the only difference being that the bearings are made to carry the weight of the impeller and the glands are just the same as in the horizontal pump.

Now the motors of most sewage pumps are electrically driven, but some of them are driven by sewage gas engines. Electrical motors for this purpose should always be explosion proof, especially if they are operating in a dry well down below the level of the floor where sewage gas may collect.

The starters and switches in connection with these pumps or with these motors should also be explosion proof. If the motor is at all liable to be flooded or if it is to run under damp conditions and the ventilation is not good the motor should be totally enclosed so as to be damp proof. Most electrical motors do not take much oiling, they require only a small amount of oil and the average electrical motor that drives a pump should be oiled only once a week or once every two weeks. Do not put too much oil on them because these bearings are ballbearings and should retain the oil almost continuously.

If your pump is being driven by a gasoline motor or by a sewage gas motor, it is important that good ventilation should be assured on the pump and on the motor. The sewage gas engine is only an adaptation of the diesel engine and the knowledge of these and the methods of keeping them up and repairing them and so on is quite beyond the scope of this lesson and if you have one of these engines you should familiarize yourself very thoroughly with the type of engine that you are using right from the manufacturer's plant and get a competent instructor to inform you all about them.

On page 8 of bulletin No. 30 D, The Smart Turner Co., you will see the average cut of an ordinary sewage pump, having ballbearings and stuffing box glands. You will see how important it is to keep oil or water under pressure within the centre of these glands so that the gland is sealed at all times. Some of the pumps have a more elaborate gland and a longer wearing one, but the illustration shows you what to expect and what you should try to arrange in the way of upkeep.

A good sewage plant, as I said before, nearly always screens or chops up the solids that come through the sewage before reaching the pump, however, if you do have occassion to have a pump and must arrange it so as to pump

raw sewage without screening, a good arrangement is by way of putting an automatic strainer such as illustrated in the booklet here and which I will leave with you, on the suction side of the pump. Another arrangement is provided by the Chicago Pump Co. in what they call their Flush Clean arrangement. In this arrangement they have two pumps one of which alternates with the other and the sewage flows down into the pump and into the tank alongside of it through a screen and then is pumped back and cleans the screen automatically when it pumps back, that keeps the pump from clogging about as satisfactorily as it can be arranged. I am also leaving with you this Flush Clean sewage ejector bulletin for your perusal.

You also see here some illustrations of Vertical Nonclog Pipes but whatever you do, remember that the glands are there to seal the suction and that they must have press ure applied to them to keep them sealed. This applies even to the small Sump Pumps and such a pump is better equipped so as to force grease from the surface down into the Sump Pump and keep the gland free from grit, if you are going to have it last. If you have a Sump Pump in an open or closed pit and the pump is always operating in the water or in the sewage, you should see that you have a grease line running from the surface so that grease can be kept under pressure preferably by means of one of the automatic grease punchers so that it will keep pressure on the glands at all times when the pump is operating.

Another arrangement for handling raw sewage without separating the screenings or the grit is by means of pneumatic sewage ejectors. These, of course, require air under pressure in considerable volume and the arrangement is so that there are a couple of large tanks which are allowed to fill with sewage and when the sewage reaches a certain point, a solenoid valve is opened so as to apply air to the surface of the sewage and to force the sewage out through a discharge pipe into the higher level. This arrangement is subject to some trouble because it is necessary to have check valves on them and these check valves sometimes clog up, but if you have a point that is subject to troube from clogging and at the same time you have available air at that point that is a type of sewage pump to consider.

Sludge Pumps

One of the most universally used modern Sludge Pumps is illustrated in Bulletin 190 D of the Chicago Pump Co., and is called a Screwpeller Pump. This is essentially a form of Turbine Pump with an impeller shaped after the shape of a screw so that incoming solids or rags or otherwise trashy material may be ground up so as to go on out

through the check valves without causing trouble. It is important in using this pump to know that the grit or sand has been removed from the sewage. The pump itself is essentially, as I said before, a Turbine Pump, the ballbearings are the same as an ordinary Turbine Pump and the gland seals are present on each side of the impeller in precisely the same way as is provided in an ordinary Turbine Pump. These gland seals must be kept greased under pressure if your pump is to last. Or it may be connected up to water pressure so as to keep a constant pressure against the glands of the pump and keep foreign material from getting into the glands. This is an especially good pump for recirculation or for pumping of sludge from one part of the plant to another.

Another type of pump that is essentially the same, is one made in England by the Pulsometer Engineering Co. called the Stereophagus Pump. This has a knife on the side of the impeller which runs against a cutting edge and shreds up foreign material which comes into the suction of the pump. The knife is accessible through a hand hole and can be removed and sharpened and fitted up to any desired clearance. This pump also has glands which must be kept under pressure either from water source or from a source of grease which is applied automatically when the pressure is on the pump.

For pumping sludge, various types of Plunger Pumps are available. These Plungers are packed with rubber and have a means of applying a ring against the packing so as to keep the plunger fairly tight. They are, however, a bit messy in that sludge is always running over the edge of them and has to be cleared away on the floor. There should be a space around them where they are mounted on the flooring with a groove so that the sludge will not escape onto the floor away from the pump, and there should also be a good drain at each pump so that it can be washed down and kept clean. These pumps are equipped on the suction and discharge side both with ball valves. These ball valves occasionally get something under them and then all you can do about it is to get to work and shut off the hand valve in front of it, open up the valve and get the obstruction out. It certainly is a messy business but there is no other way of doing it. In installing these pumps, there should be a hand operated plug valve, preferably a lubricated one, on the suction and discharge between the sludge line and the ball valve so that you can isolate this pump and do anything with it. They are all equipped with an air cell so as to form a cushion on the discharge and this is important. Lubrication is usually done by means of grease cups which are operated manually and the motors driving them are usually hooked

up with a chain drive so that only the ordinary attention is necessary to the motor. The chain drives, however, must be kept oiled at all times and it is preferable to have a mechanical oiler on these so that the oiler works when the pump runs. These pumps come in single, duplicate, triplicate and quadruplicate pistons, for smaller and larger sizes. They are very dependable where the sludge contains foreign matter such as sand or other material liable to clog the pipe. A number of different types of these pumps are illustrated in the Bulletins to be given to you to be circulated amongst yourselves.

Another type of Sludge Pump that is very useful for pumping the sludge or slurry from one point to another, is available where there is air pressure in the plant. This is a very good method of handling sludge since it is totally enclosed and the only parts that move are the diaphram and the solenoid valve on the air line. The diaphram pump is furnished by the Oliver Uniter Filters and is usually used in circulating sludge for drying purposes to the filters and away from them.

Blowers

Most sewage plants employ blowers in one form or another either for furnishing air to pre-treatment aerator tanks or by way of furnishing air to the aerator tanks. In most modern plants these are known as rotary air compressors and exhaustors. They are motor driven in the same fashion as a centrifugal pump and require about the same sort of attention. The blowers are mostly water cooled and the water furnished to the cooling glands is used to seal the glands of the blower in about the same manner as a centrifugal pump. It is most important that sufficient water be available and should be used to keep these blowers cool.

These blowers come in single and multiple units which can be driven by a single motor and are illustrated in the pamphlet which is enclosed herewith.

Some of these compressors are air-cooled for the smaller jobs and these units that are air-cooled are exceptionally light in weight and lubrication is effected by means of balanced pressure feed oil cups. It is most important that these oil cups should be kept in working condition. It is better to waste a little oil along with these compressors than to have them running dry and consequently getting hot. It is also important to see that the air ducts are kept open.

Sewage Pumps G.G. Reid

Some of the sewage plants are equipped so as to recirculate or circulate sewage gas in which case you will have an adaption of this blower fixed up so that it will handle sewage gas. With these arrangements, it is most important that the motor should be totally enclosed and explosion proof as well as all electrical arrangements in connection with it. An oil pump is used to circulate oil to the glands and the pump, and it is important that this oiler should be in constant use and should be working at all times. There is an indicator on the top of the oil tank which shows the circulation of the oil and it is important that this should be examined every day to see that it is working properly.

In installing these gas blowers, provision should be made for pressure regulators so that the pressure in the blower will be constant at all times. It is also important to have a definite arrangement for draining the condensing water from the gas lines before it enters the blower. This is accomplished by an ordinary gas trap and it is important to see that this condensation trap is working at all times and that it is kept empty.

There are many problems arising in sewage treatment and in the operation of sewage plants that are not covered in connection with this discourse, but it has been necessary to shorten it if we are to cover the one subject at all. I have not attempted to cover the design of pumps or blowers as it is felt that the sewage operator should know the cardinal principles of looking after the machine rather than the design of it.

USES OF CHLORINE IN SEWAGE TREATMENT

The use of chlorine in sewage treatment that we are most familiar with is its use as a disinfectant. Where it is necessary to discharge an effluent with a very low bacterial count, chlorination is usually the best answer. There are, however, several other occasions in sewage treatment where chlorine can be very useful.

Control of Septic Conditions and Odours

Usually, when odours are a problem in handling sewage, a septic or anaerobic condition is the cause and when one is eliminated the other is corrected. There is the case of low velocity in sewers allowing solids to settle and become septic. This situation can be controlled by chlorination of the sewage at a point above where the trouble occurs.

We also have the case of trade wastes such as come from packing houses, canneries, milk plants, etc., they have very high oxygen demands and become septic before they reach the sewage plants. This situation can also be cured by chlorination of the waste as it leaves the factory.

An anaerobic condition in a primary clarifier will interfere with the settling of the suspended solids and also create an odour problem if the effluent from the clarifier is aerated in an activated sludge plant. Chlorination of the influent to the clarifier can be used quite effectively to control this situation.

The supernatant liquor from digesters can be considered as another anaerobic problem in sewage treatment. Chlorination of the supernatant to reduce its high oxygen demand would reduce a very troublesome problem in many sewage plants.

Chlorination is not the answer to all the problems caused by anaerobic conditions as in some cases it may prove too costly but even then it can be used as a control until, a better answer is found.

Reduction of B.O.D.

The ability of chlorine to oxidize many organic compounds can sometimes be utilized in reduction of B.O.D. This does not always work out advantageously as in some instances it only changes the organic compounds so that there is an increase in the immediate B.O.D. even though it has reduced the total B.O.D.

Activated Sludge

Chlorine can be useful in activated sludge plants that are overloaded. The best place for the application of the chlorine in such plants can only be determined by experimentation. Sometimes, it is most effective to add it in the aeration channels where it aids in oxidation. At other times, the most benefit is obtained by adding it to the influent final clarifier to control biological activity and maintain an an aerobic condition. It is also possible that splitting the dosage and adding it at both places may be the most effective treatment.

If an activated sludge plant has become septic, bleaching powder is more effective than chlorine gas in restoring the plant to normal conditions. The lime in the bleach raises the pH of the sewage at the same time that the chlorine is returning it to an aerobic condition. Care should be taken that the bleaching powder is not added at too high a rate. As it is possible to plug the diffuser plates with calcium carbonate if the pH is raised too high.

Control of Chlorination

Where an odourous and septic condition exists, it is usual to increase the dosage until the desired results are obtained. It has been found that a dosage of approximately 60% of the chlorine demand will usually be adequate.

For disinfection, chlorine should be added until a residual is obtained. A residual of 0.5 ppm after 15 minutes contact should be adequate. If bacterial analysis shows that this residual is not adequate, it will, of course, be necessary to increase it.

It must be remembered that the chlorine demand of a sewage effluent will vary greatly during a day and the residual should be adjusted during a period of peak chlorine demand.

At present there are three ways recommended for the determination of chlorine residual:

(a) Ortho tolidine
(b) Starch iodide
(c) Amperometric

The Ortho tolidine test is the simplest of the three, but there is some controversy as to whether it is satisfactory for measuring chlorine residual of sewage. If it is found that Ortho tolidine does not give adequate control, it may be necessary to use one of the other two methods.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: THE INSTRUMENTATION OF SEWAGE WORKS

Instructor: G. T. G. Scott

The purpose of this lecture is to describe the various types of instruments that are available and to give some indication of their operation and maintenance. Before doing this it might be well to discuss briefly the reasons behind the instrumentation of sewage works.

In order to be able to operate a treatment works efficiently it is essential to have accurate information concerning the physical quantities that are passing through the various units in the works. Likewise it is essential to have available long range records of performance so that the overall efficiency and cost of operation may be ascertained from time to time.

In a small works sufficient information for these purposes may be obtained from a simple recorder measuring the flow into the works. As the size of the works increases so the complexity of operation makes it necessary to measure various flows throughout the works. Where industrial or trade wastes have to be dealt with it may even be necessary to provide automatic pH indicators and other similar instruments.

The instruments provided in a sewage works are required to measure a variety of things including raw and treated sewage, raw, digested and activated sludges, and the flows of air and sludge gas. Meters are also required for the measurement of electrical energy.

A large number of measuring devices are available. Space does not permit a consideration of all these but the more common devices installed in sewage works will be discussed.

The Measurement of Flow in Open Channels and Conduits.

Instruments designed to measure the flow in open channels or conduits are based on the determination of the velocity of flow through a device with a known cross-sectional area. As the velocity of flow is directly proportional to the head or liquid level above the device, measurement of this head provides a direct indication of the flow through the device. These instruments are known as head-area meters.

(a) Weirs.

A weir is in effect a dam or bulkhead containing a notch or recess through which the liquid to be

measured falls freely to a lower level. The level of the liquid below the weir must be below the crest of the weir, i.e., the bottom of the recess or notch, so as to allow a free fall. Weirs of various shapes are used, the two commonest being the rectangular and the V-notch.

Owing to the drawdown effect adjacent to the weir, the point at which the head is measured must be upstream from the weir, a distance of at least three times the maximum head that is to be measured.

Flumes

(b) A flume is a constriction in an open channel or conduit, the flow characteristics of which are accurately known.

One of the more common types of flume used is the Parshall flume. This consists of an entrance section with converging walls and level floor, a constricted throat section with parallel walls and downstream sloping floor and a recovery section with diverging walls and a rising floor. The head is measured at a point one-third of the length of the converging section below the start of the flume. The accuracy of a flume is dependent on the accuracy with which it is built and the dimensions of flumes must therefore be held to close tolerances.

Open flow nozzles.

(c) Flow nozzles are constricted outlets specially designed to be placed at the end of a pipe flowing partly full and discharging with a free fall. The flow through the nozzle is, as is the case with all head-area meters, proportionate to the head above the nozzle. This head is measured by means of a small tapping in the bottom of the pipe just upstream from the nozzle.

The method of measuring the head is similar for all head-area meters. A small pipe is led from the point at which the head is to be measured to an adjacent stilling box or float chamber. Changes in the liquid level are transmitted to the meter by means of a float, cable and counterweight. The cable passes around a drum attached to a cam. Rotation of the cam operates themechanism of the meter through a series of levers.

Measurement of Flow under Pressure in Pipes.

The rate of flow through a pipe is governed by the velocity and pressure in the pipe. A constriction in the pipe will

cause a change in the velocity of flow and this will be accompanied by a change in pressure or head. This basic principle is utilized in the differential head meter.

(a) Venturi Tubes.
A Venturi tube is a section of pipeline specially designed to facilitate the measurement of changes in pressure or head due to variations in the velocity of flow. It consists of several sections, including a conical reducing section, a cylindrical throat section and a diverging outlet cone. This constriction causes changes in pressure which are measured at two points; one just upstream of the inlet cone and the other in the centre of the throat section. From the difference in pressure at these two points it is possible to calculate the flow through the tube.

(b) Dall Flow Tubes.
The Dall tube is a Venturi type differential producer. It consists of a flanged cylindrical body design with a short inlet section terminating with an abrupt decrease in diameter, or "inlet shoulder", which is followed by a conical restriction and a diverging inlet separated by a narrow annular ring or throat into which opens a single pressure hole tap. A single hole tap also exists at the inlet. The theory of operation is similar to that of a Venturi tube.

(c) The Orifice.
An Orifice consists of a thin flat plate with a hole in the centre of it which is inserted in the pipe. By means of tappings upstream and downstream of the orifice the loss of head or pressure through the orifice may be determined and the flow through the pipe calculated.

Each of the differential head meters described above is provided with two pressure tapping points. Pipes are led from these tapping points to the meter where the pressure differential is converted to a mechanical movement which operates the meter.

Pumps.

Both reciprocating and centrifugal pumps may be used for measuring purposes. This is normally accomplished by measuring the number of cycles of operation of the pump which can then be used as a measure of the total flow. This is relatively simple with controlled volume reciprocating pumps, as these give a constant output for each cycle

of operation. Centrifugal pumps however, if used for measuring purposes, must be calibrated for each different speed of operation, suction lift and discharge pressure.

Pitot Tubes.

A Pitot tube is a device for determining the velocity in a conduit of known cross-sectional area. The device consists of a vertical tube with a tip at right angles, the tip being inserted in the flow and facing upstream. The pressure produced in the tube by the flow in the conduit is a function of the velocity of the flow and hence the rate of flow. For measuring the flow in pipes under pressure a variation is used in which a pressure tap is provided in the side of the pipe at right angles to the flow. The differential pressure between the two is again a function of the velocity and the rate of flow. It is measured in a similar manner to the method used for pressure differential devices described above.

Velocity Meters.

These are devices which, by means of a vane or propeller inserted in a pipeline measure the velocity of flow in that pipe. When used in an open channel, this device is called a current meter. The revolutions of the propeller are transmitted mechanically to the meter.

Conveyor Scale Metering.

Many of the larger treatment plants are now being equipped with some form of mechanical drying for the sludge. Conveyor systems are normally used for the transportation of the sludge. A scale mechanism can be incorporated in the conveyor so as to measure continuously the quantity of dried sludge passing along it. The mechanism weighs the loaded belt as it passes and at the same time subtracts the weight of the return belt plus any material adhering to it. In this way a true net weight of the sludge passing is obtained.

pH Recorders.

Where industrial or trade wastes are to be accepted by a sewage works it is important to have a record of the acidity or alkalinity of the sewage entering the works. This record may be obtained by the use of a pH recorder, which consists of a primary element inserted in the liquid and a recording meter. The operation of this instrument is based on the principle that if two solutions of different pH are separated by a thin glass membrane, a difference of potential is established between the two solutions, and this difference is

a function of the difference in pH value. The meter measures this difference in potential and records it as the pH value of the liquid being measured.

Types of Meters

There are three main types of meter in common use. These are:-

(a) The indicator which gives an indication of the rate of flow in c.f.s., g.p.m., or any other units as required.

(b) The recorder which records the rate of flow continuously on a chart.

(c) The totalizer which provides a running total of the flow up to the time of observation.

These meters may be obtained separately or in any combination. Probably the two most common combinations used in sewage works are the totalizer-recorder, and the totalizer-indicator-recorder.

Under certain circumstances it is neither convenient nor possible to locate the meter adjacent to the point at which the flow is to be measured. In such cases it is necessary to transmit the information electrically or pneumatically to the point where it is required.

There are various forms of electrical transmission that can be used. One of the most common in sewage works practice is the time impulse type. The transmitter has a device containing a cam, a synchronous motor and a mechanically operated mercury switch. The cam is rotated by the synchronous motor at a constant speed, usually revolving once every fifteen seconds. As the cam rotates it moves the magnet away from the mercury switch, causing the switch to close. The cam shoe arm is positioned by the information received from the measuring device. The length of time that the cam shoe rides on the cam face determines the time the switch is closed and this time interval varies in direct proportion to the flow being measured. The signal so produced can be transmitted any distance from a few feet to many miles. It actuates a receiving instrument which may be an indicator, a recorder, or a totalizer. It can also be used to operate pumps, valves or similar equipment.

In another type of transmitter the information produced by the measuring device is used to operate a contact which moves along a resistance coil. This coil is in circuit with an electrical receiving instrument and the voltage impressed

on the receiving instrument is determined by the position of the transmitter contact on the resistance coil. In other words, the voltage is proportional to the rate of flow.

Methods of pneumatic transmission are based on the use of proportionate air pressures from 3 to 15 p.s.i. A cam operated bleed valve controls the pressure in the system in such a way that it is always proportionate to the rate of flow or level being transmitted.

Maintenance.

The cause of much serious trouble in measuring devices is the accumulation of foreign bodies.

In head-area meters this will take the form of sewage solids which will accumulate behind a weir or in a float chamber. Some method is therefore normally provided to enable the operator to clean out these areas. The accumulation of solids in a float chamber may be prevented by periodically allowing a flow of water to pass into the float chamber. This will flush out the float chamber and the pipe connecting the chamber to the channel or conduit.

The taps from differential head or pressure meters may become plugged with solids. For this reason the tappings are normally provided with probes which can be used for cleaning the openings. Where this type of meter is used for measuring sludge, the taps are flushed continuously with fresh water so as to keep them clear. Deposits and growths of slime on weirs, orifice edges and any other metering devices will cause changes in the flow characteristics and consequent errors in measuring. The only remedy for this is regular cleaning.

The variety of types of meters are too numerous to allow the laying down of set rules and regulations for their maintenance. However, there are certain general principles that should be borne in mind if these meters are to give long and trouble-free service. Most manufacturers supply with their instruments an Instruction Manual. These should be studied thoroughly in order to obtain complete and accurate information as to the construction, operation and maintenance for each different type of meter. The manufacturer will also specify the type of tools that should be used for proper maintenance. These and only these tools should be used, as the use of the wrong tool may cause irreparable damage.

Moving parts in a meter will wear in due course and they should be inspected regularly so that replacements can be made as soon as they become necessary. Spare parts should always be available for this purpose. A program of preventive maintenance should be drawn up so that each and every

instrument is inspected, cleaned and lubricated at regular intervals.

To sum up, the only way to obtain satisfactory service from the instruments in a sewage works is to ensure that they are never neglected nor abused.

(f) "sewage works" means any public works for the collection, transmission, treatment or disposal of sewage, or any part of any such works;

(g) "sewage rate" means a charge for the capital cost of sewage works.

Sewer rate

(2) Subject to the approval of the Municipal Board first being obtained, the council of a local municipality, in authorizing the construction of sewage works may, by by-law, provide for imposing upon owners or occupants of land who derive or will or may derive a benefit from the sewage works a sewer rate sufficient to pay for the whole or such portion or percentage of the capital cost of the sewage works as the by-law may specify and, with the like approval, such by-law may from time to time be amended or repealed.

Special assessment under R.S.O. 1950 c.215

(3) Where a sewer rate is imposed under subsection 2, no part of the capital cost of the sewage works shall be specially assessed under THE LOCAL IMPROVEMENT ACT.

Land in respect of which sewer rate is imposed

(4) A by-law passed under subsection 2 shall designate the land for which the owners or occupants are made liable for the sewer rate imposed and, where the land designated does not comprise all land within the municipality, the area thereof shall be defined in the by-law.

Idem

(5) The land designated under subsection 4 may include not only land for which an immediate benefit accrues but also land for which a deferred benefit accrues.

Sewer rate for deferred benefit

(6) Where a sewer rate is imposed for a deferred benefit, it shall be changed to a sewer rate imposed for immediate benefit as soon as the immediate benefit is derived or derivable.

Computation of rate

(7) A sewer rate shall be computed by any or all or any combination of the following methods:

(a) a foot frontage rate on the lands which receive an immediate benefit from the work;

(b) a foot frontage rate on the lands which receive a deferred benefit from the work;

(c) an acreage rate or rates on any or all of the lands designated under subsection 4 which rates may differ as between lands which will receive an immediate benefit and lands which receive a deferred benefit;

(d) a rate on that portion of the lands designated under subsection 4 and which are connected to the sewage works based on the water rates or charges charged or chargeable in respect of such lands;

(e) a mill rate on the assessed value of the lands designated under subsection 4.

Revenue from sewer rates (8) The revenue derived in any year from a sewer rate imposed under subsection 2 shall be applied and used towards payment of principal and interest due in that year upon debentures issued for the sewage works for the capital cost of which the sewer rate is imposed, and the council shall reduce the amount of the debenture rate to be levied for such debentures in any year upon the rateable property liable therefore by the amount of revenue estimated to be derived in that year from the sewer rate.

Sewer rate for cost of existing sewage works (9) Where in a local municipality there is land which has not or the owners or occupants of which have not been and are not assessable or taxed with respect to an existing sewage works except in the same manner and to the same extent as all other owners or occupants of land within the municipality have been or are assessable or taxed and a sewer forming part of such existing sewage works is to be constructed by means of which an immediate benefit from the existing sewage works accrues to the owners or occupants of such land, the council may, by by-law passed with the approval of the Municipal Board, provide for imposing upon the owners or occupants so benefited a sewer rate sufficient to pay for such portion or percentage of the capital cost of the existing sewage works as the by-law may specify.

Idem (10) A sewer rate may be imposed under subsection 9 not withstanding that the capital cost of the existing sewage works has in whole or in part been paid.

Revenue from sewer rate (11) The revenue from the sewer rate imposed under subsection 9 if not required for payment of any part of the outstanding capital cost of the existing sewage works shall be applied and used only for future capital improvements of the existing sewage works.

Sewer rate in addition to sewer rate under sbs. 2

(12) A sewer rate imposed under subsection 9 shall be separate from and in addition to the sewer rate, if any, imposed under subsection 2 upon the same owners or occupants with respect to the sewer to be constructed to form part of the existing sewage works.

Sewer rate structure

(13) The council of a local municipality for the purposes of subsections 2 and 9 may, by by-law passed with the approval of the Municipal Board, establish a sewer rate structure upon which sewer rates imposed under subsection 2 or 9 shall be based and calculated and, in establishing the rate structure, the council shall have regard to differentiating between the several classes of works, the kinds of benefits accruing and all other relevant matters to ensure that sewer rates are imposed upon a basis that is equitable and just, and, with the like approval, a by-law establishing the rate structure may from time to time be amended or replaced.

Sewage service rate

(14) The council of a local municipality may by-by-law provide for imposing upon owners or occupants of land who use sewage works a sewage service rate.

Idem

(15) A sewage service rate may be imposed under subsection 14 notwithstanding that,

(a) a sewer rate has also been imposed with respect to the capital cost of the same work; and

(b) the work with respect to which it is imposed was constructed under THE LOCAL IMPROVEMENT ACT or any other general or special Act.

Sewage service rate structure

(16) The council of a local municipality for the purposes of subsection 14 may by by-law establish a sewage service rates structure upon which sewage service rates shall be based and calculated and, in establishing the rate structure, the council shall have regard to differentiating between classes of users, nature, volume and frequency of use and all other relevant matters to ensure that sewage service rates are imposed upon a basis that is equitable and just.

Collection of rates

(17) The council of a local municipality may, by by-law, establish systems for,

(a) fixing times, periods and frequencies at and for which sewer rates imposed and under subsection 2 or 9 and sewage service rates imposed under subsection 14 shall be payable; and they may be yearly, half-yearly, quarterly or bi-monthly;

(b) allowing discounts for prompt payment of such rates or for adding penalties for non-payment by due date;

(c) appointing persons, corporations or agencies to have charge of and the power and responsibility for billing and collecting such rates;

(d) billing and collecting such rates and for co-ordinating such billing and collecting with the billing and collecting of other kinds of rates or charges imposed by or for the corporation;

(e) any other relevant matter or thing.

Idem

(18) The council of a local municipality may, by by-law, require any public utilities commission or local board which supplies water to the inhabitants of the municipality to collect such portion of any sewer rate or sewage service rate as is computed by the method referred to in clause (d) of subsection 7.

Rates to be charged on land

(19) A sewer rate imposed under subsection 2 or 9 and a sewage service rate imposed under subsection 14 upon any owner or occupant of land shall be a lien and charge upon the land and, if the same or any part thereof remains unpaid after due date, the amount unpaid may be collected by distress upon the goods and chattels of such owner or occupant, or the clerk of the municipality, upon notice to him of the amount due, the person by whom it is due and the land upon which a lien is claimed, shall enter the same upon the collector's roll and the collector shall proceed to collect the same in the same way, as nearly as may be, as municipal taxes are collectable.

SEWAGE WORKS OPERATORS' COURSE NO.1

February 20-24, 1956

SUBJECT: DIGESTION - THEORY AND DESIGN

Instructor: R.V. Anderson

A. THEORY

Sludge from the sewage treatment process is composed of the settled solids from the bottom of primary sedimentation tanks, scum from the surface of primary tanks, and excess activated sludge from the aeration process of activated sludge systems. This semi-liquid mass, with a moisture content of from 94% to 96% is treated in a separate tank (or tanks) known as a "digester".

In the digester, over a period of 10 to 30 days, various changes take place in the original raw sludge which are both bio-chemical and mechanical. An anaerobic bacterial process takes place which converts the sewage solids to stabilized reduced forms (i.e. digested sludge) and to a clear but highly contaminated liquid portion known as "supernatant liquor", and to combustible gases known as "digester gas".

The mechanical action that takes place is a simple separation to the bottom of the tank of the wet compact sludge from the supernatant liquor, with the gas accumulating at the top of the tank.

In a single tank these processes go on simultaneously and we have what is known as "single stage digestion".

By the use of two tanks the processes can be separated with improved results. First, the sludge is mixed continuously at constant temperature in the first tank which stimulates the bio-chemical action, resulting in maximum gas generation and decomposition of the sludge solids. The digested sludge in this liquid form is then transferred gradually to the second tank where the solids settle and compact as sludge, and the supernatant liquor floats on top in the upper portion of the tank.

The biological activity in the digester depends upon two totally different groups of bacteria thriving together under the same conditions. It is important that these bacteria have the proper environment for their active reproduction.

One group, which is present in sewage sludge in great numbers, attacks complex organic substances, such as fats, carbohydrates, and proteins, and converts them to simple organic compounds. Some of these organisms are acid-forming bacteria which can produce fatty acids in such quantities

that the pH of the digester is lowered to such a level that all biological activity is arrested and the digestion process ceases.

Opposing this tendency is a second group of organisms, known as methane-forming bacteria which reproduce at an active rate when the pH is held from 6.5 to 8.0. This bacteria is capable of utilizing the acid and other end-products formed by the first group of organisms. Unfortunately, these organisms do not occur in great numbers in raw sewage sludge nor do these reproduce as fast as the acid-forming bacteria, and if organic acids are formed faster than the methane-forming bacteria can absorb them, the pH in the tank may be still further lowered.

To combat this occurrence a strong digesting sludge tends to produce a natural buffering substance, which neutralizes the organic acids, prevents a serious drop in pH, and allows the methane-formers to gain in numbers and do their necessary work. Primary sludge is poor in buffering capacity, whereas actively digesting mixtures are much richer, due to the presence of bicarbonates of calcium, magnesium and ammonia. The calcium and magnesium bicarbonates are formed largely from the decomposition of calcium and magnesium soaps, and the ammonium bicarbonate from the bacterial decomposition of proteins.

Since the volatile acids present in a digester should not exceed 2,000 p.p.m. and the pH should not drop below 6.8 there is a natural tendency to attempt to arrive at these conditions by the addition of lime to a digester if it has not been performing as it should. The history of this practice has been so varied that it is not recommended, for it has been claimed in some cases to have had no effect, and in others to be actually detrimental. A safer procedure is to control the operation of the digester in such a manner that the optimum conditions are present to encourage the formation and activity of the methane-forming bacteria.

If lime is added to correct acidity it may be done by adding it in the form of milk of lime to the raw sludge entering the tank, at the rate of 5 to 10 lbs. of hydrated lime per day per 1,000 persons population. The process might have to continue for many weeks or months, and is known as "liming the tanks".

Conditions in a digestion tank may be considered satisfactory when:

1. The methane content of gas produced lies between 55 and 75 percent, averaging about 65 percent, and the carbon dioxide content averages about 30 percent.
2. The digested sludge has about 10 percent dry solids, of which 50 percent is volatile matter.
3. The pH of the digested sludge is between 7.0 and 8.0.
4. The volatile acids do not exceed 2,000 p.p.m. in the digestion tank.

5. Grease is practically absent from digest sludge.

6. The digested sludge is black, quickly drainable, noticeably viscous in flow, and inoffensive in odour, musty rather than putrescible.

The above requirements are most nearly realized when conditions in the digester are such that the micro-organisms perform at their maximum efficiency. They require no rest period but do require ideal conditions to thrive and break down the organic material throughout the digestion process, Maintenance of these conditions depends upon:

1. Temperature - should be uniform throughout the entire tank contents, and heat must be supplied to keep the sludge temperature at not less than 85°F. At this temperature in a single stage digester the biochemical process is completed in 30 days. At 70°F it takes 40 days, at 55°F 120 days, and in Canadian winter temperature without added heat no digestion at all takes place. Hence, in the latter situation no reduction in volume takes place, no gas is produced, and the digester only acts as a holding or storage tank for raw sludge.

2. Uniform Feeding of Raw Sludge - Micro-organisms must be supplied with new food supplies at a uniform rate, and in such a way that intimate contact results. This condition is not properly realized by irregular batch pumpings of cold primary raw sludge to a single discharge point in a large tank. Intimate mixing is desirable, either by mechanical means, recirculation, or by gas diffusion at the bottom of the digester. The importance of this mixing principle has only recently been realized, and the more violent and complete the mixing, the faster the rate of digestion. In addition to uniform feeding of raw sludge, if its water content can be reduced a double advantage occurs by concentrating the food producing qualities for the use of the micro-organisms, and by eliminating the space in the digester usually taken up by the supernatant liquor. A sludge thickener tank placed ahead of the digester reduces the volume of the raw sludge by as much as 50%, returns this liquid portion back to the primary clarifier, and permits more uniform application of concentrated sludge to the digester. It also thus permits rapid and continuous mixing of the digester without requiring a second digester tank for separation of sludge and digester liquor, as the supernatant liquor is eliminated.

Another important advantage is that there is less material in the digester to require heating, and the consumption of fuel is reduced.

3. Volatile Acid Control - Control of volatile acids can be used successfully to foretell the approach of conditions which retard digestion. An undesirable change in volatile acid content, as indicated by the "Standard Methods Test", provides warning of impending difficulty long before a change in pH or alkalinity, a drop in gas production rate, or foaming indicates trouble is at hand.

Routine determinations of volatile acids should be made. A concentration value of 1,200 to 2,000 p.p.m. may be considered normal. If the tests show a higher and increasing value from 2,000 p.p.m. the following steps may be taken to correct the situation:

(i) Divert incoming primary raw solids to another digester if one is available.
(ii) Circulate digested sludge within the overloaded digester which will tend to reduce the volatile acids content and increase gas production.

B. DIGESTER DESIGN

General

Before designing any one part of a separate sludge digestion system the entire process operation must be completely worked out, from the receiving point of the raw material which is raw sludge, to the end point of the finished product which may be digested liquid sludge, or dried sludge, or incinerated sludge. Certain by-products develop along the line of the flowsheet, such as digester gas, and supernatant liquor, and a solution for handling these items must also be included in the design. The best over-all arrangement to fit the particular plant under consideration is the proper design, but just as there are variations in primary and secondary sewage treatment plant design, so are there marked differences in the designs of digester systems.

An effort has been made to arrive at certain fundamental standards in sewage works practice, and a report was prepared in 1951 by the Upper Mississippi River Board and the Great Lakes Board of Public Health Engineers, covering ten states, and known as "Tentative Standards for Sewage Works" which summarizes in part the design requirements of sludge digestion and disposal somewhat as follows:

A. General

(1) Multiple Units: Multiple digestion tanks are recommended. Where this is not practical, it is desirable to have a lagoon or open tank for emergency use so that the digester can be taken out of service without unduly interrupting plant operation.

(2) Depth: The proportion of depth to diameter should be such as to allow for the formation of a reasonable depth of supernatant liquor.

(3) Maintenance Provisions: To facilitate emptying, cleaning, and maintenance the following features are desirable.

(a) Slope - The digester bottom should slope at least three inches per foot toward the withdrawal piping unless the tank is provided with sludge collection mechanism.

(b) Access Manholes - At least two access manholes should be provided in the top of the digester in addition to the gas dome. One opening should preferably be large enough to permit the use of mechanical equipment to remove grit and sand.

(c) Safety - Non-sparking tools, rubber soled shoes, safety harness, gas detectors for inflammable and toxic gases, and gas masks of the hose or oxygen helmet type should be provided.

(4) Sludge Inlets: Provision should be made for the recirculation of sludge. One inlet should discharge above the liquid level and be located at approximately the center of the tank unless mechanical scum breakers are employed. The raw sludge inlet line should discharge at a point at least the radius of the digester from the supernatant drawoffs.

B. Capacity

(1) Solids Basis: Where the composition of the sewage has been established, digestion tank capacity may be computed from the volume and character of sludge to be digested. Due allowance should be made for sludge storage and supernatant.

(2) Population Basis: Where these data are not available, the following unit capacities should be used for plants treating domestic sewage. The capacities should be increased by allowing for the suspended solids population equivalent of any industrial wastes in the sewage, and may be reduced if the sludge is dewatered mechanically. Volumes should be calculated on the basis of the bottom having planes sloping thirty degrees from the horizontal upward from the end of the withdrawal pipe unless sludge moving equipment is installed.

Type of Plant	Cubic Feet Per Capita	
	Heated	Unheated
Imhoff tanks		3 to 4
Primary	2 to 3	4 to 6
Primary plus standard filter	3 to 4	6 to 8
Primary plus high-rate filter	4 to 5	8 to 10
Activated sludge	4 to 6	8 to 12

For small installations (population 5,000 or less) consideration should be given to using the larger values. Additional capacity shall be provided where garbage solids are anticipated.

C. Gas Collection, Piping, and Appurtenances

(1) General: All portions of the gas system including the space above the digester liquor, storage facilities and piping should be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under pressure. All points where any gas leakage might conceivably occur should be adequately ventilated and separated from areas where extraneous sparks, fires, or lights might occur. The use of a common wall between a digester and a general control building is not recommended.

(2) Safety Equipment: All necessary safety facilities should be incorporated where gas is produced. Pressure and vacuum relief valves and flame traps are essential. Water seal equipment should not be installed.

(3) Gas Piping and Condensate: Gas piping should be at least 2½ inches in diameter and should slope to condensation traps at low points. The use of float controlled condensate traps is not permitted.

(4) Gas Utilization Equipment: Gas burning boilers, engines, etc., should be located at ground level and in well ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.

(5) Electrical Fixtures: Electrical fixtures in enclosed places where gas may accumulate shall comply with the National Board of Fire Underwriters' specifications for hazardous conditions.

(6) Waste Gas: Waste gas burners should be located at least 25 feet away from any plant structure if placed at ground level, or may be located on the roof of the control building if sufficiently removed from the digesters. In remote locations, it may be permissible

to discharge the gas to the atmosphere through a return-bend screened vent terminating at least ten feet above the walking surface provided the assembly incorporates a flame trap.

(7) Ventilation: Any underground enclosures connecting with digesters or containing sludge or gas piping shall be provided with forced ventilation which should be in operation, preferably automatically, during occupancy.

(8) A gas meter with by-pass should be provided.

D. Digester Heating

(1) Insulation: Wherever possible digestion tanks should be constructed above the ground-water level and should be suitably insulated with dirt embankments or by other means.

(2) Heating Facilities: Hot water coils for heating digesters should be at least two inches in diameter and the coils as well as the support brackets should be of cast or wrought iron. The use of dissimilar materials should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock. Consideration should be given to heating installations embodying heat exchangers or some form of heating device which can be readily removed from the tank for maintenance. Other methods of heating digesters which may be developed will be considered on their individual merits.

(3) Heating Capacity: Sufficient heating capacity should be provided to maintain the sludge at 85° to 95°F. or more at all times.

(4) Mixing Valves: A suitable automatic mixing valve should be provided to temper the boiler water with return coil water so that the inlet water to the coils can be held to a temperature of 140°F. or less. Manual control should also be provided by suitable by-pass valves.

(5) Boiler Controls: The boiler should be provided with suitable automatic controls to maintain the boiler temperature at 180°F. or more to minimize corrosion and to shut off the main gas supply in the event of pilot burner or electrical failure.

(6) Thermometers: Thermometers should be provided to show temperatures of the sludge, hot water feed and hot water return.

E. Supernatant Withdrawal

(1) Piping Size: Supernatant piping should not be less than six inches in diameter.

(2) Withdrawal Arrangements:

(a) Withdrawal Levels-Piping should be arranged so that withdrawal can be made from three or more levels in the tank. A positive unvalved overflow shall be provided.

(b) Withdrawal Selection-On fixed cover digesters the supernatant withdrawal level should preferably be selected by means of interchangeable extensions at the discharge end of the piping.

(c) Supernatant Selector - If a supernatant selector is provided, provision shall be made for at least one other draw-off level located in the supernatant zone of the tank, in addition to the unvalved emergency supernatant draw-off pipe.

(3) Sampling: Provision should be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1½" in diameter.

(4) Emergency Supernatant Disposal: An emergency disposal method for the supernatant liquor in the form of a lagoon or an additional sand bed should be provided for use in case supernatant is not suitable or other conditions make it advisable not to return it to the plant. In large plants consideration should be given to supernatant conditioning.

F. Sludge Pumps and Piping

(1) Sludge Pumps:

(a) Capacity: Pump capacities should be adequate but not excessive. Provision for varying pump capacity is desirable.

(b) Duplicate Units: Duplicate units shall be provided where failure of one unit would seriously hamper plant operation.

(c) Type: Screw feed or plunger pumps should be provided for handling raw sludge.

(d) Minimum Head: A minimum positive head of 24 inches shall be provided at the suction side of centrifugal type pumps and is desirable for all types of sludge pumps. Maximum suction lifts should not exceed 10'.

(e) Sampling Facilities: Unless sludge sampling facilities are otherwise provided, quick closing sampling valves shall be installed at the sludge pumps. The size of valve and piping should be at least 1½".

(2) Sludge Piping:

(a) Size and Head: Sludge withdrawal piping should have a minimum diameter of eight inches for gravity withdrawal and six inches for suction. Sludge pump discharge piping should be at least 4" in diameter. Where withdrawal is by gravity the available head on the discharge pipe should be at least four feet and preferably more.

(b) Slope: Gravity piping should be laid on uniform grade and alignment. Slope on gravity discharge piping should not be less than 3 percent. Provision should be made for draining and flushing discharge lines.

G. Sludge Drying Beds

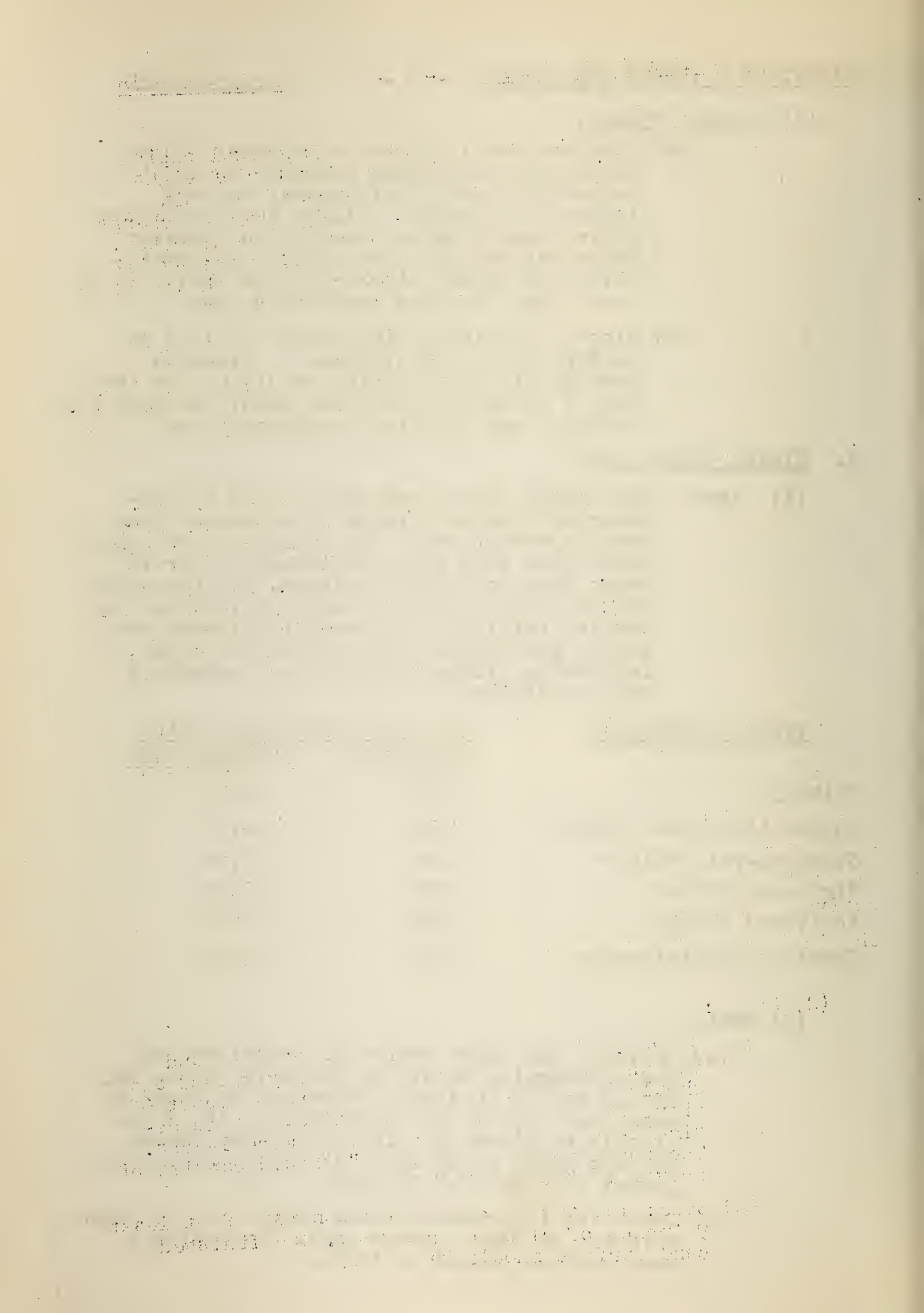
(1) Area: The sludge drying bed area needed for dewatering digested sludge is dependent upon weather conditions. The following per capita areas have been found satisfactory for the area: North of 45°N. Latitude. Consideration should also be given to areas which have excessive rainfall. No specific figures are given, but consideration should be given to increasing sludge bed area to accommodate such conditions.

Type of Treatment	Area in Square Feet/Capita	
	Open Beds	Covered Beds
Primary	1.25	1.00
Intermittent sand filter	1.25	1.00
Standard-rate filter	1.50	1.25
High-rate filter	2.00	1.50
Activated sludge	2.00	1.75
Chemical precipitation	2.50	2.00

(2) Media:

(a) Gravel: The lower course of gravel around the underdrains should be properly graded and should be 12" in depth, extending at least 6" above the top of the underdrains. It is desirable to place this in two or more layers. The top layer of at least 3" should consist of gravel 1/8" to 1/4" in size.

(b) Sand: The top course should consist of at least 9 inches of clean coarse sand. The finished sand surface should be level.



(3) Underdrains: Underdrains should be bell and spigot vitrified clay pipe at least 4" in diameter laid with open joints. Underdrains should be spaced not more than 20 feet apart.

(4) Walls: Walls should be water-tight and extend approximately 15 inches above and at least 6 inches below the sand surface. Outer walls should be curbed to prevent soil from washing on the beds. On glass covered beds, walls and walkways should be designed to minimize shading on beds.

(5) Sludge Removal: Not less than two beds should be provided and they should be arranged to facilitate sludge removal. Concrete truck tracks should be provided for all sludge beds. Pairs of tracks should be on 20' centers.

(6) Sludge Influent: The sludge pipe to the beds should terminate at least 12 inches above the sand surface, and be so arranged that it will drain. Concrete splash plates should be provided at sludge discharge points.

(7) Drainage Disposal: Drainage from beds should be returned to the raw or settled sewage, if possible. Where chlorination is required, the filtrate shall be returned to a point preceding the chlorination process.

The foregoing report of the Joint Committee is intended as a guide rather than a comprehensive and complete treatment of the subject and it is intended that the standards would be subject to change to correspond to advances in engineering design. Comments in the light of present day practice and trends, on various sections of the Joint Committee report are as follows:

A. General

(1) Multiple Units:

Two stage digestion in separate tanks is preferred since only the primary stage need be equipped for heat control, stirring or mixing, and gas collection, with the secondary tank being used as a storage tank for consolidation of sludge and separation from the supernatant liquor. The digestive action is most rapid during the first stage, with more than half of the total gas from each increment of raw sludge being given off in the first 24 hours. Only 6 to 8 days of digestion period is required in the primary stage and 22 to 24 days in the secondary stage, as compared to a 30-day digestion period in a single stage digester. With a 2-stage system any of the recent devices for producing high digestion can be installed in the primary stage tank, such as intimate mixing by recirculation or mechanical stirring, or by gas diffusion at the bottom of the tank, along with heat control and gas collection, but without supernatant withdrawal, as no supernatant can accumulate at the top of a tank undergoing active and thorough mixing.

(2) Depth:

The side depth of the wall in most tanks is about 20 feet. Most tanks are circular, with a cone-shaped hopper bottom for the accumulation of sludge to a centre draw-off point.

(3) Slope:

A recommended slope of 3 inches per foot, or 1 vertical to 4 horizontal is steeper than some manufacturer's recommendations of 1 in 6, but is to be much preferred if structural conditions will permit. The necessity of such a requirement is apparent when it has been found in some digesters opened up for cleaning that a compacted layer of grit and sand and sludge has formed at a 30 degree angle to the horizontal on the bottom of the digester, thus reducing the effective capacity of the tank by the volume of the compacted mass at the bottom of the side walls and over the tank bottom.

B. Capacity

(1) Solids Basis:

If the quantity and quality of the suspended matter in a crude sewage and in the raw sludge are known or are estimated, the quantities of sludge produced at various stages of treatment can be predicted. The dry solids per capita in domestic sewage average 0.16 to 0.17 pounds per day, depending on the suspended solids value of the actual sewage. In a primary sewage treatment plant the dry solids per capita in the digested sludge may approximate 0.06 pounds per capita per day, or 0.11 pounds per capita per day for an activated sludge plant.

The primary and secondary tanks should take out 90% of the original solids in the domestic sewage with a moisture content of 95%, or about 20 times the weight of the dry solids alone. Converting this to cubic feet the volume of wet sludge produced per day is known.

The net decrease in this daily volume due to the digestion process is about 25% for an activated sludge plant, so that the daily increases in sludge volume in the digester are only 75%. Now these daily increments of volume must be held in the digester throughout the whole digestion process and until sludge withdrawal takes place. This time factor should be taken as 60 days for a controlled, heated digester, to allow for peak loadings, irregularities in sludge withdrawals, and a fair margin of safety.

Hence, the required volume of the tank can be calculated on the foregoing basis.

(2) Population Basis:

Recent publications on successful trial runs of"high-rate" digestion processes may tend to question the capacity basis of the table, which requires 4 to 6 cu. ft. per capita for an activated sludge plant. However, caution should be exercised before reducing these capacity figures, for other requirements are often needed to make the "high-rate" method feasible, and these cannot always be provided in a small plant.

These requirements include-

(1) Intimate mixing of digester contents by gas diffusion, re-circulation or mechanical stirrers.

(2) Controlled heat of 85° to 95°F.

(3) Provision for almost continuous raw sludge feed and corresponding withdrawal of digested sludge at uniform rates. To achieve this it is desirable to have a raw sludge thickening tank and a second stage sludge holding tank.

(4) Skilled operating personnel to control the chemical and mechanical requirements of high-rate digestion.

C. Gas Collection, Piping and Appurtenances

No mention is made in the Joint Committee report under this heading of the advantages of floating covers for digesters. There are many advantages in using a floating cover particularly for small plants. The advantages in using a floating cover particularly over a fixed cover are as follows:

(1) Fewer Scum troubles because solids are constantly submerged.

(2) When fresh sludge is added to the tank, or digested sludge or supernatant liquor is withdrawn, it is unnecessary to remove or to add an equal amount of supernatant liquor or sludge, as must be done in a tank with a fixed cover.

(3) Danger of mixing oxygen with the gas to form an explosive mixture is minimized.

(4) It is not always necessary to provide a gas holder unless a large reserve supply of gas is needed.

Gas Utilization is deserving of further comment.

In heat value 1,000 cubic feet of sludge digestion gas is equivalent to about 600 cubic feet of natural gas, 6.4 gallons of butane, 5.2 gallons of gasoline, or 4.6 gallons of Diesel oil (U.S. gallons).

One cubic foot of sludge gas has a heat value of about 730 B.T.U.'s.

A heated digester will produce gas at the rate of from 0.61 to 0.69 cubic feet per capita per day, or about 15 to 18 cubic feet per pound of volatile solids added to the tank which represent about 2/3 of the total solids reaching the digester.

The quantity and quality of gas produced are probably the best indices of the progress of digestion.

Gas storage is necessary when excess gas is used for heating and the generation of power to operate pumps, air blowers and generators. This is due to the irregular rate at which gas is given off, and the changing rate of consumption demand.

If the demand is constant and all the gas is used, a storage tank with a capacity of about 110 to 115 percent of the daily gas yield should be installed. If 10 percent of the gas can be wasted, then a holder with a capacity of only 40 percent of the daily gas generation is needed.

Gas storage tanks may be of the floating asometer type, dry seal gasometer, or pressure tank held at 30 to 45 lbs. per sq. inch by means of a gas compressor.

In small plants digester gas is frequently used only for heating the digester. A heat balance can be worked out for the total number of B.T.U's available from the combustion of the generated gas. Generally speaking for a population of 4,000 and up the digester gas is sufficient to provide all the fuel necessary to heat the digester, but supplementary heat sources at the boiler should also be provided, such as city gas or fuel oil.

D. Digester Heating

The report of the Joint Committee recognizes inside hot water coil heating, but also advocates heat exchangers or other means of external heating that can easily be maintained without emptying the tank and disrupting the digestion process. The trend is towards "external heat exchanger" housed in a separate control room adjacent to the digester. It has been found desirable to circulate the upper two-thirds of the digester contents through the tubes of the exchanger once every 24 to 48 hours, with velocities in the heating tubes to be kept to about 4 feet per second. Heaters are made in sizes from 1000,000 to 1,000,000 B.T.U.'s per hour, and are designed to be fully automatic, with provision made for alternative types of fuel, and with proper protective and safety devices incorporated in the design.

Other method of heating sludge-digestion tanks include:

(1) Injection of live steam into the contents of the digestion tank.

(2) Direct heating by submerged combustion in a small sludge heating tank located on top or adjacent to the digester.

E. Sludge Drying

In addition to sludge drying beds as described in the Joint Committee report there are other well known methods of disposing of digested sludge.

These include:

(a) Disposal in liquid sludge by tank truck over agricultural land.

(b) De-watering on vacuum filters and disposal of the sludge cake as a fertilizer or by incinerator.

(c) Burning of liquid sludge in a special type of sludge incinerator.

Where continuous vacuum filters are used the filtering process is aided by the use of elutriation. This consists of washing the sludge with water, by mixing the sludge and water together in the ratio of 1 to 1, or 2 of water to 1 of sludge, by means of a mechanical mixer or diffused air, for a period of about 10 minutes. The mixture is allowed to settle, and the supernatant liquor is drawn off. The sludge is then conditioned with chemicals before applying it to the vacuum filters for drying.

SPECIAL PROCESSES FOR AIDING OR INCREASING THE RATE OF SLUDGE DIGESTION

1. Catalytic Process

A proprietary process supplied by the Chicago Pump Co. which returns compressed digester gas to the bottom of the digester through diffusion tubes, thus causing the tank contents to rise in the center and draw down on the sides and across the digester bottom, producing a very intimate mixing of the raw and partially digested sludge, the supernatant and the gas. The results show a complete digestion of the sludge in as little as 10 days. To operate successfully a second holding tank is necessary for the storage and consolidation of sludge, and the withdrawing of supernatant. Heat control, and even feeding of raw sludge and the uniform withdrawing of the digested mixture are still important.

2. Densludge Process

The great effect of water content upon sludge volume was pointed out by Steel who said, "It is important to recognize the great changes in sludge volume brought about by relatively small changes in water content and the consequent advantage in obtaining sludge with low percentages of moisture.

A device developed by the Dorr Co. for thickening raw sludge from the primary and secondary tanks before pumping the raw sludge to the digester decreases the sludge volumes up to 50%.

The process is carried out in a circular sedimentation tank with overflow surface weir and sludge draw-off arrangement at the centre of the cone-shaped bottom. A slowly rotating picket-fence type of scraper moves the settled sludge to the draw-off pipe. The effluent is returned to the primary settling tank. The thickened sludge digests more rapidly, due to increased gas activity, and the size of digester is reduced due to the reduction in volume of the incoming sludge mixture because of the lower moisture content. No supernatant withdrawal is said to be required in the digester, because the equivalent of the supernatant is already disposed of in the effluent of the thickener, before it gets to the digester.

3. Perth Gas Process

A proprietary process supplied by the Pacific Flush Tank Co. It consists of piping compressed digester gas into the digester at several points through vertical tubes spaced around the cover of the digester, and to a variable depth in the upper zone of the tank. The action of the dispersed gas causes increased digester activity and scum dispersion with low-cost and freedom from operational difficulties.

CONCLUSION

It is hoped that the foregoing treatise on the theory and design of digesters will be of interest to plant operators, will assist in understanding what is taking place in the digestion process, and will raise the question - "Is my plant equipment adequate; is it possible to improve the present operation; and would the addition of new devices or the changing of the present arrangement increase the rate and quality of digestion?" If this paper causes the operator to cast a critical eye on his present plant and encourages him to adopt scientific digester control it will have achieved its purpose.

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SEWAGE WORKS OPERATORS' COURSE

Subject: SEWAGE SERVICE RATES

Instructor: A. E. BERRY

INTRODUCTION:

The financing of sewage works projects is important to all who are involved in this field. The Operator should know the procedures as well as does the Administrator or other Municipal Official.

CAPITAL COSTS AND CURRENT COSTS

It is well to distinguish between capital costs and current costs as follows:-

(a) The capital for a sewage works project is paid back over a period of years. This time may extend from ten or thirty years.

(b) Current expenditures are met out of the current taxes or other revenue of the municipality raised during the current year.

Each municipality operating a sewage works system must raise each year the amount of money needed to pay the capital charges and the operating charges or current costs. These are not allowed to accumulate and be carried over from one year to another. Each municipality is subject to the authority of provincial legislation.

DEBENTURES

It is customary for municipalities to finance the capital costs of sewage works by the issue of debentures or bonds. In this way the municipality is able to borrow the total amount required for the capital cost of the project. This then, is paid back along with the interest during the period of the debenture. These capital payments are made either as serial bonds or sinking funds. In the former, the same amount is paid each year that the debenture runs. This amounts to a certain part of the principal together with interest. The amount of interest will vary each year, but the total of the two payments will be the same for the period of the debenture. In the sinking fund plan, no principal is paid until the end of the debenture payment. In the meantime, the municipality sets aside a certain amount of money which is invested and which at the end of the debenture period should be sufficient to

pay off the entire capital cost. The sinking fund method is generally used by the provincial governments and the federal government but not so much by municipalities.

METHODS OF RAISING MONEY

A municipality operating sewage works must raise each year the amount required for capital costs as well as for the current or operating costs. There are different ways in which this money can be secured from the ratepayers. Some of the methods include the following:

(a) General taxation based on the assessment of the property.
(b) A frontage charge under The Local Improvement Act.
(c) Sewer rates.
(d) Sewage service rates.
(e) Various charges made to municipalities and institutions.

The municipality is faced with the problem of adjusting the rates in the most equitable manner. This means allocation of costs among the various users. An effort should be made to charge each user an amount in proportion to the benefit he derives from that service. That is why these different procedures are in use. They may be used separately or combined together.

Some features of the different methods of raising money are given herewith.

GENERAL TAXATION

When this system of raising money is followed each one pays according to the assessment of his property. Thus, the charge is not based on the benefits derived but rather on "ability to pay." It is assumed that the person who has the highest assessment is able to pay the highest amount for the sewage works. Since this is the principle upon which the financing of general expenditures in municipalities is based it is reasonable to place part of the annual cost for the sewerage system on general taxation. Just what this should be is always a problem.

THE LOCAL IMPROVEMENT ACT

This is used for the construction of sewers. Under this procedure the property owner pays a definite amount per foot frontage and accordingly if he has a wide lot he

per cent of the capital cost. The sinking fund
method is commonly used by the provincial governments
and the federal government but not so much by
municipalities.

[illegible] Sinking Fund

A municipality operating a [illegible] must
pay over the amount required for capital costs as
well as the current or operating costs. There are
different ways in which this money can be secured
the municipality. Some of the methods include the fo

(a) [illegible] annually out of the [illegible]
revenue.
(b) [illegible] charge under the local improvement
(c) [illegible] taxes.
(d) [illegible] service rates.
(e) [illegible] sinking fund to municipally [illegible]
institutions.

[illegible] principally is faced with the [illegible]
obtaining the money in the most economical manner.
This means [illegible] costs among the various [illegible]
[illegible] should be spread over [illegible]
in proportion [illegible] the benefits from their use.
There is only three different procedures one [illegible]
may be used separately or combined together.

These measures of the different methods of meeting
money are given below:

Special Rates

[illegible] system of raising money is followed when
[illegible] to the [illegible] of the property.
Thus, the charge is set based on the benefits derived
from using or [illegible] it may," [illegible] that
[illegible] on the [illegible] arrangement is only to pay [illegible]
[illegible] amount for [illegible] works. Since this is
[illegible] when [illegible] [illegible] [illegible]
the [illegible] is [illegible] to [illegible]
of the annual cost for this [illegible] [illegible]
tion. Over what this should be is always a problem.

[illegible] Taxation

This is used for the construction of sewers. Under
this procedure the property owner pays a definite amount
[illegible] and accordingly if he has a wide [illegible]

will pay a larger amount than the person who has a narrow lot. This system has been in use for many years. It is somewhat cumbersome to employ but it has a number of advantages. It is a good practice to add a part, at any rate, of the cost of the necessary sewage works under the Local Improvement procedure.

SEWER RENTAL SCHEMES

There is a tendency to-day for the use of sewer rental or sewage service procedures. In this way it is felt that there is a greater share of the project being charged according to the benefit derived. This is somewhat similar to the payment made by the property owner for electric lights and for water. In those instances he pays according to the amount of the product he consumes.

In Ontario, Section 389 of The Municipal Act authorizes municipalities to charge sewer rates and sewage service rates. The details of this procedure are set out in The Act, and it is well for each person to be familiar with what is permitted under this legislation.

Sewage service rates can be charged in a number of different bases. One of the most common of these is to add the cost to the water bill. It is generally added as a proportion of the cost of water, thus it may be 50%, 75% or 100% of the water bill. Another procedure is to charge a flat rate based on the kind of service supplied. This also can be added to the water bill. Other measures which can be employed include: assessment of the property, number of rooms in the house, or any other method which appears reasonable. The amount in each case can be added to the water bill if that is the method by which it is to be collected.

A DESIRABLE METHOD OF FINANCING

When a municipality has to raise money to pay for a complete sewerage system a desirable procedure is to divide the cost under a number of different methods. These may include the following:

(a) A specific amount on the frontage of the property especially to pay for the sewers.
(b) A percentage of the water bill such as 50-100% which will be considered as a sewage service rate.
(c) The balance of the cost to be paid out of general taxes and based on assessment.

will ask a lawyer sooner than the person who has a water lot. This system has been in use for many years. It is somewhat overbearing in regard to its use & making of advantages. It is a good practice to, if part, if by mail, of the cost of the necessary legal work under the local improvement procedure.

[illegible] Utility

There is a customary tendency for the use or owner [illegible] damage or delay [illegible]. In this way it is felt [illegible] is a greater share of the project being proposed [illegible] according to the benefit derived. This is measured [illegible] by the payment made by the property owner for electric [illegible] and for water. In these instances he pays on [illegible] the amount of the product he consumes.

In general, Section 3(3) of the Municipal Act [illegible] municipal utility to charge sewer rates [illegible] service rates. The details of this procedure [illegible] set out in the Act, and it is not [illegible] [illegible] with what is required under this Act.

[illegible] service rates can be charged in a number [illegible] ways. One of the most common of these [illegible] to use water bill. It is generally [illegible] consumption of the user, thus it may [illegible] on [illegible] of the water bill. Another procedure [illegible] [illegible] used on the kind of service supplied [illegible] can be on the water bill. Other measure [illegible] to [illegible] whether assessment by the property [illegible] of acres in the area, or any other method which [illegible] The amount in most cases can be added [illegible] [illegible] what is the period by which it is [illegible].

[illegible] [illegible]

[illegible] possibility has to raise money to pay [illegible] [illegible] system a desirable procedure is to divide [illegible] a number of different methods. These may [illegible] as follows:

[illegible] amount on the frontage of the property [illegible] usually to pay for the sewers.
[illegible] percentage of the water bill such as 50-100% which will be considered as a service rate.
[illegible] the balance of the cost to be paid out of general [illegible] and based on assessment.

This combination of procedures has a number of advantages. It can be used to pay both current and capital costs. An example of this which is applicable in some municipalities would consist of the following:

(a) A frontage rate at 20¢ per foot.

(b) Sewage service rate - 75% of the water bill.

(c) General taxation - about 2 or 3 mills.

It is for the Municipal Council to determine which method will be used in financing these works.

ONTARIO WATER RESOURCES COMMISSION ACTIVITIES

The Ontario Water Resources Commission Act enables a municipality to make an agreement with the Water Resources Commission whereby the work will be done for the municipality. In this way the Commission will undertake to design, build, finance and operate the sewage works. The municipality then will not have to raise any debentures or bonds but will have to pay a certain amount each year to the Water Resources Commission. This yearly amount will be the actual cost of financing the project. It will include capital cost, interest and operating charges.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: DIGESTION-OPERATION AND MAINTENANCE

Instructor: D. P. Scott

I sometimes wonder if maintenance of digestion tanks and, in fact, all sewage treatment, might not be handled better by the ladies, since so much of the work is just good housekeeping. Besides this, in a digestion tank, there are more bacteria than there are people on the earth, and each of these bacteria is just like a baby. It requires food, warmth, proper conditions in which to live, and removal of waste.

The bacteria in the digestion tank should be fed often but not too much at one time. They should be given concentrated food, which is not diluted with too much water.

In mesophilic digestion, the temperature should be maintained between 90°F. and 95°F. In thermophilic digestion, which uses a different breed of bacteria, the temperature should be maintained in the neighbourhood of 130°F. Because of the difficulties attending the operation of a thermophilic digestion tank, most sewage treatment plants use mesophilic digestion.

There are two methods in general practice used for heating the digestion tanks. One is circulating hot water through pipes or coils immersed in the sludge in the digestion tank. The hot water in these pipes should not be allowed to reach a temperature above 130°F. as, otherwise, sludge may become caked on the pipes and prevent the transmission of the heat from the water to the sludge. The second method of heating the digestion tank is to circulate the sludge through pipes immersed in a bath of hot water, either in a sludge heater or a heat exchanger. Again, the water should not be allowed to become much hotter than 130°F. as, in this case, the sludge would cake on the inside of the tubes. However, in the case of the sludge heater or heat exchanger, provision is usually made so that these tubes can be cleaned much more easily than the coils inside a digester.

In order to prevent the bacteria from receiving a chill, the raw sludge should be mixed with the heated sludge before being discharged in the digester.

In order to provide the proper conditions for the bacteria, it is necessary to check the pH, that is, the acidity or alkalinity of the contents of the digestion tanks. By adding too much raw sludge to the tank at one time, the volatile acids in the tank may be increased to such an extent that the bacteria are killed. By feeding septic sludge or certain industrial wastes to the tank, conditions may be created in which the bacteria are unable to live.

Instructor: E. J. Scott

[illegible]

[illegible]

[illegible]

The pH of a tank operating under proper conditions should be about 7. The volatile acids, which are measured in the supernatant should not exceed 200 parts per million.

The digested sludge should be drawn off from the bottom of the tank consistently. If insufficient sludge is drawn off, the digested sludge will take up too much room in the tank and leave insufficient space for the digestion process. If too much sludge is drawn off at one time, insufficient seed may be left in the tank to start digestion in the raw sludge fed to the tank. As an example, at one of our plants, in preparation for the Christmas and New Year's season, the digested sludge was drawn off and filtered on vacuum filters. In an effort to complete this work for the whole holiday season, too much digested sludge was drawn off. As a result, early in the new year, it was found that the volatile acids were rising rapidly. In some tanks, the volatile acids reach 3,000 parts per million. It was necessary to stop entirely feeding raw sludge to the digestion tanks. Fortunately, it was possible to filter the raw sludge directly on the vacuum filters and dispose of it without digestion until the volatile acids in the digestion tanks came back to near normal. When pumping sludge from a digestion tank, care must be taken not to create a vacuum. A vacuum may cause air to be drawn into the tank which, with the gas, may form an explosive mixture. If the vacuum relief valve does not operated, it is possible to create sufficient vacuum to collapse the tank.

One of the products of the process of digestion is a combustible gas, which is frequently used to heat the digester and provide fuel for the plant generally. A digester which is operating properly produces methand, CH_4. Safety precautions must be taken to prevent air or oxygen becoming mixed with the gas, which would form an explosive mixture and , in case this does happen, flame traps are placed in the gas pipe lines to prevent the ignition of the gas. The flame trap is subject to freezing if it is outside, as the moisture in the gas will condense in the flame trap and freeze and, on occasion, will completely block the flow of the gas. The resulting build-up of gas pressure should be relieved by the pressure relief valve. However, when this is out doors, it can also be frozen closed and not provide the relief required.

Condensed moisture will cause considerable trouble, even when not subject to freezing. Since the digestion tank is hot, considerable water vapour will be carried with the gas and, when this condenses in the gas lines, any low part of the pipe line will become full of water. This will seriously interfere with the even flow of the gas to any burner where it is being used. It is therefore necessary to have a drip trap installed at any low point in the gas line to drain off water which may collect there.

The normal hand-operated drip trap consists of a small container in which the water may collect. The trap has two valves which generally operate simultaneously. The one on the connection between the gas line and the container is normally left in the open position. The second valve, which, when open, allows the water to drain from the reservoir, is normally left closed. When the valves are operated, the first is closed, which prevents the gas flowing to the reservoir, and the second is opened, which allows any water which has collected to run out.

In some of our installations, we have replaced the hand-operated drip trap with a simple installation which is automatic. This is shown in the accompanying sketch and consists of a large reservoir attached directly to the low point in the gas line. This reservoir must have a vertical height measured in inches greater than the maximum gas pressure measured in inches of water. The outlet pipe which is connected to the bottom of the reservoir rises vertically to a level near the top of the reservoir. This then forms a trap, which requires greater pressure than the maximum gas pressure to discharge all the water in the bottom, but will discharge the excess water as soon as the difference between the level in the reservoir and the overflow pipe is equal to the gas pressure in inches of water and sufficient water has collected to raise the level in the overflow pipe to its discharge point at the top.

One of the difficulties encountered in the operation of digesters is caused by sand or grit collecting in the bottom of the digester. This collects around the sides and takes up space which should be available for the process of digestion. On occasion, the sand will slide down to the withdrawal point in a mass and block the pipe line. The sand, of course, should not be allowed to enter the digester and should be taken out before it reaches the digester by the grit removal equipment.

Another serious difficulty is encountered by the formation of scum in the digester. A scum is usually formed of fibrous materials carried in the sewage, combined with grease, which digests comparatively slowly and floats to the top of the liquid in the digester.

At the Main Sewage Treatment Plant in Metropolitan Toronto, the scum in each of the four digesters increases at the rate of approximately one foot per month. As you can see, this poses a very serious problem in the operation of these digesters. This rate of accumulation of scum has been reduced somewhat recently, due to the operations of the Industrial Waste Control Branch, by obtaining the co-operation of industry in removing some of the material which forms scum at the source.

On occasion, the scum blankets at the Main Plant have reached a thickness of 18 feet. You should realize that such a blanket constitutes a threat to the roof of the digester.

For example, if the clearance between the bottom of the roof and the normal operating level of the liquid is 24 inches and the normal gas pressure 16 inches, then suppose that one foot of scum would float one inch above the surface. Then 18 feet of scum would float 18 inches above the surface. This would give a clearance of only six inches between the bottom of the roof and the top of the scum blanket. Then, if the gas pressure of 16 inches were suddenly released; the scum blanket would tend to float 16 inches higher, but, as there is only six inches clearance, considerable pressure would be exerted by the scum blanket on any projections below the roof or pipe lines suspended on the roof of the digester.

At the Main Plant, experiments have been conducted with gas re-circulation to reduce the scum blanket. This has prevented the formation of the blanket to a considerable extent but has not as yet, entirely eliminated the problem. From time to time, the scum blankets which normally are quite solid, have been softened up by the introduction of compressed air, using a 600 c.f.m. compressor at the bottom of the tank. This seems to agitate the blanket with the rest of the sludge, and after 24 hours of such treatment, the blanket will remain soft for a period of four or five days. During this period, it is drawn off through overflow pipes and dried directly on vacuum filters. Although this is drawn off as fast as possible, one such treatment usually results in a reduction in the blanket of only three or four feet.

The starting of a new digester, either at a new plant or in connection with an enlargement to an old plant, or after an old digester has been cleaned, presents a special problem.. In the case of the digester at a new plant, where the initial flow is very low and even a flow equal to half the capacity of the plant is not expected for a year or two, the gradual build-up of the load in the digester will not cause any great difficulty. As many sewage treatment plants are put in operation in this way, the operators are not aware of the difficulties that can be encountered when a digester is started under conditions of a heavier flow. If the new plant is to receive the sewage draining from a built-up area that is already sewered, considerable care should be exercised in the manner of loading the digestion tank.

At Cincinnati recently, the digestion tanks were loaded in what appeared to be a reasonable manner. However, after several months, it was found that the volatile acids in the digesters were up to 5,000 parts per million, and that proper digestion was not taking place. No improvement was noted in the digesters, even when loading was stopped and they were left for a considerable period of time. Eventually, these digesters had to be cleaned out completely and scrubbed, and loading started all over again.

It is recommerded that the loading be based on 0.3 pounds of volatile solids per cubic foot of digester capacity per month. This might be approximately one tenth the rate of normal loading. Even with this reduced rate of feed, the volatile acids should be watched closely and, if they show a tendency to rise, the rate of feed should be reduced or stopped until this tendency changes.

The operator should understand his plant processes sufficiently to be able to make various calculations in regard to the flow of sewage and solids through his plant. The following two problems are examples of such calculations in connection with digesters:-

(1.a) WHAT ARE THE NUMBER OF GALLONS OF SLUDGE TO BE PUMPED TO A DIGESTER IF THE FEED IS TO BE LIMITED TO 0.3 POUNDS OF VOLATILE SOLIDS PER CUBIC FOOT OF DIGESTER CAPACITY PER MONTH?

Assumptions:

Diameter of digester - 40 ft.
Average depth of liquid - 24 ft.
Solids in sludge are 70% volatile
Sludge being pumped is 6% solids
1 Imperial gallon = 10 lbs.

Area of digester = $40 \times 40 \times \frac{11}{4}$ = 1250 sq. ft.

Volume of digester = 1250 x 24 = 30,000 cu. ft.

Number of pounds of volatile solids to be fed to the digester per month = 30,000 x 0.3 = 9,000 lbs. per month.

Number of pounds of volatile solids to be fed to the digester per day = $\frac{9,000}{30}$ = 300 lbs. per day

Number of pounds of solids in the sludge to be fed to digester per day = $300 \times \frac{100}{70}$ = 428 lbs. per day

Number of pounds of sludge to be pumped to the digester per day = $428 \times \frac{100}{6}$ = 7130 lbs. per day

Number of gallons of sludge to be pumped to the digester per day = $7130 \times \frac{1}{10}$ = 713 gallons per day

(1.b) IF THE SLUDGE PUMP HANDLES 60 GALLONS PER MINUTE, WHAT IS THE CORRECT PUMPING TIME REQUIRED TO PUMP 713 GALLONS OF SLUDGE PER DAY TO THE DIGESTER?

Time of pumping = $\frac{713}{60} = 11.8$, or about 12 minutes per day

If the pump is to be operated four times a day, it therefore should be used only three minutes each time, while pumping the sludge. Frequently, a sludge pump seems to pump a certain

amount of water that may have accumulated in the sludge piping before it actually starts pumping the sludge.

(2) IF A PRIMARY SEDIMENTATION PLANT IS RECEIVING AN AVERAGE FLOW OF TWO MILLION G.P.D. OF SEWAGE CONTAINING 204 P.P.M. SUSPENDED SOLIDS, (a) HOW MANY POUNDS OF SOLIDS ARE PUMPED TO THE DIGESTION TANK PER DAY, (b) HOW MANY GALLONS OF SLUDGE ARE PUMPED TO THE DIGESTION TANK PER DAY, (c) WHAT IS THE PERCENTAGE REDUCTION OF SOLIDS IN THE DIGESTER, (d) HOW MANY POUNDS OF DIGESTED SLUDGE SHOULD BE REMOVED FROM THE DIGESTION TANK PER DAY, AND (e) HOW MANY GALLONS OF DIGESTED SLUDGE SHOULD BE PUMPED OUT OF THE DIGESTION TANK PER DAY?

Assumptions:

80 lbs. of grit are removed daily
The primary sedimentation tanks remove 55% of the suspended solids
The volatile solids in the raw sludge are 75% of the suspended solids
The volatile solids in the digested sludge are 45% of the solids
The primary sludge is 6% solids
The digested sludge is 5% solids

Number of pounds sewage coming into the plant = 2,000,000 x 10
= 20,000,000 lbs. per day

Number of pounds of solids coming into the plant $\frac{204}{1,000,000}$ x 20,000,000 = 4080 lbs. per day

Number of pounds of solids going to primary sedimentation tanks = 4080 - 80 = 4,000 lbs per day

Number of pounds of solids in the sludge removed from the primary sedimentation tanks to the digesters = $\frac{55}{100}$ x 4,000
= 2200 lbs per day (a)

Number of gallons of sludge pumped to the digester = $\frac{2200}{10} \times \frac{100}{6}$
= 3660 gals. per day (b)

Number of pounds of volatile solids in raw sludge = $\frac{75}{100}$ x 2200
= 1650 lbs. per day

Number of pounds of non-volatile solids in raw sludge = 2200 - 1650 = 550 lbs. per day

Number of pounds of non-volatile solids in digested sludge = 550 lbs. per day

Percentage of non-volatile solids in digested sludge = 100 - 45 = 55%

Number of pounds of solids in digested sludge = $\frac{100}{55}$ x 550
= 1000 lbs. per day

Percentage reduction of solids in digestion = $\frac{2200 - 1000}{2200}$ x 100%

$= \frac{54.5\%}{}$ (c)

Number of pounds of digested sludge = $1000 \times \frac{100}{5} = \frac{20{,}000 \text{ lbs.}}{}$ per day (d)

Number of gallons of digested sludge to be pumped out of the digester $= \frac{20{,}000}{10} = 2000$ gals. per day (e)

SEWAGE WORKS OPERATOR'S COURSE

February 20-24, 1956

SUBJECT: ACTIVATED SLUDGE - DESIGN AND OPERATION

Instructor: J. W. MacLaren

Theory of Activated Sludge

Mr. Caverly has discussed with you, I understand, primary treatment and the removal of the settleable solids and certain suspended solids from the sewage. Since he has given full coverage to this portion of the work it is not necessary for me to refer to primary treatment as far as activated sludge plant design is concerned. I do wish to make it clear, however, that the primary treatment of sewage when preceding biological treatment does not have to be as extensive in its retention or removals as may be required when it represents the sole type of treatment being given to the sewage. However, it is still, in my opinion, a very necessary part of any plant assigned for complete biological treatment.

In any case we are still left with approximately forty to fifty percent of the suspended solids and sixty-five to seventy-five percent of the B.O.D. in the sewage following primary treatment and this may only be materially reduced through some form of biological treatment. This remaining material is either dissolved or suspended, being in any case sixty to eighty percent volatile or combustible (solids which cause odour nuisances if they do not decompose in a controlled manner).

The volatile solids are usually found in one of three classifications - carbohydrates, proteins, or fats. Their total strength is generally measured by the B.O.D. test which gives an approximate indication of the air required to oxidize such pollutants to a stable end-point. Certain errors in the B.O.D. process, however, are making it abundantly clear that this parameter must some day soon be superseded by a more efficient test, and even now the work of Buswell and his associates indicate the B.O.D. test should be carried out in three stages, one to determine the carbonaceous demand, one to determine the air requirements for oxidizing nitrogenous material from ammonia to nitrites and thirdly for oxidixing nitrogenous material from nitrites to nitrates.

Carbohydrates consist of carbon, oxygen and hydrogen in definite proportions and are represented best in typical sewage by starches and sugars. Certain sewages contain them in strength in view of certain industrial wastes present in the

sewage such as the wastes from the brewing or distillery industries or from the fruit canning industry. Certain forms such as sugars are easily broken down but in other forms such as the cellulose in toilet paper, considerable time is taken to break down the carbohydrate. In the breakdown of a carbohydrate through the death of a plant or animal, decay, fermentation or putrefaction takes place, resulting ultimately in the formation of carbon dioxide, if such action takes place under aerobic conditions or if the decomposition occurs through putrification in the formation of methane due to anaerobic conditions. In turn the carbon from the CO_2 so generated is assimilated by plants and is used by the chlorophyll in that plant for its development in conjunction with sunlight. Animals may then feed on the plant and change the carbohydrate contained therein to some extent and develop proteins and fats therefrom and eventually on the death of the animal the carbohydrate once more returns to the stage of decay, fermentation and putrefaction as we find it in sewage.

Proteins contain carbon, oxygen and hydrogen plus nitrogen or sulphur and are, of course, always present in sewage being present in more than normal concentration when the sewage contains large concentrations of dairy or packing house wastes. Proteins are present in dead plants or animals and undergo decay with the resulting formation of ammonia. This ammonia is not stable and can be used by some bacteria as food. Such bacteria we call nitrifiers and they oxidize the ammonia through nitrification to unstable nitrites and further oxidize this material to stable nitrates. These nitrates are then consumed as food in the growth of plants which in turn serve as food for animals who further develop the protein matter which, as in the case of carbohydrate, commences to break down upon the death of the plant or animal to its original state as we found it in the sewage. We therefore have a change in the condition of nitrogen from the plant to the animal, to the urea, to ammonia to nitrites, to nitrates and back to plant. Sulphur follows a somewhat similar cycle to nitrogen in the putrefaction of protein matter but we should remember that it is in the uncontrolled putrefaction of sulphur that most of our odours in connection with sewage treatment plants occur through the formation of the undesirable hydrogen sulphide.

Fats are formed of carbon, oxygen and hydrogen the same components as carbohydrates but in a different relative proportion and although they can be broken down by bacteria in the same manner as carbohydrates and proteins, considerably more air is required per unit weight of fats in their oxidation than is required in the case of carbohydrates or proteins. The remainder of the load or solid content in sewage reaching the biological treatment facilities is composed of mineral salts which of course do not represent an organic demand nor generally a problem in sewage treatment with one main exception (mineral oil). In certain instances these salts have been

instilled into the sewage through actual trade wastes and could represent a problem but on the whole they remain unchanged from the time they are first encountered in the water supply until they leave the sewage treatment plant in its effluent.

The control, decay and oxidation of carbohydrates, proteins and fats through biological treatment such as trickling filters or activated sludge is the problem of the sewage plant designer and even more the problem of the sewage plant operator. Carbohydrates, proteins and fats are present in sewage in addition to bacteria in three forms - a suspended form, a colleidal form and a dissolved form and the latter two are responsible for the cloudy colour in sewage. When settled sewage is aerated for protracted periods these three types of particles will coalesce to form light feathery floc which settles slowly upon quiescent standing. The supernatant liquor remaining following such settlement will be relatively clear. If this liquor is decanted and discarded and the thin sludge is re-aerated in a second batch of settled sewage a shorter period will suffice to produce clarification and more sludge will result. If this cycle is repeated several times it will be found at first that as the amount of sludge increases the clarification time decreases but eventually a point will be reached beyond which further increments of sludge are of little or no value in improving the clarification time. At that point clarification generally is found to occur within 30 to 40 minutes.

During this process of flocculation and clarification many of the bacteria and protozoa in the sewage are absorbed on or enmeshed in the floc. In the presence of abundant dissolved oxygen some forms die off or remain dormant while others multiply rapidly. By the action of their growth these latter organisms convert the pollutant absorbed on the sludge or dissolved in the sewage to carbon dioxide, sulphates, nitrates and the living protoplasm of their own bodies. This process is termed biological oxidization and takes place in either the trickling filter or activated sludge type of biological treatment. During its progress bacterial enzymes are secreted which hasten the clarification.

It is important to remember that flocculation, clarification, and oxidization as encountered in the activated sludge process are dependent on biological activity which in turn is dependent on oxygen. Without the biological activity flocculation would be slower, clarification less complete and oxidization might not occur at all. Both oxidization and clarification take place more rapidly when the sludge and sewage are first brought together providing there is sufficient oxygen available, but unlike clarification, oxidization cannot be completed in a few minutes and may take several hours or even days. Unless sufficient time is allowed between cycles

for oxidization to catch up with adsorption, the settleability of the sludge deteriorates and if oxidization continues to lag, the clarifying power of the sludge is also reduced.

In summary therefore the activated sludge process is officially defined in the glossary of terms recently published by the American Public Health Association, The American Society of Civil Engineers, The American Water Works Association and The Federation of Sewage Works as follows: "The activated sludge process consists in the agitation of a mixture of sewage with about 15 percent or more of its volume of bacterially active liquid sludge in the presence of ample atospheric oxygen, for a sufficient period of time to coagulate at least large proportions of the colloidal substances followed by sedimentation adequate to the substance of the sludge floc, the activated sludge having been previously produced by aeration of successive quantities of sewage and maintained in condition by adequate aeration."

This process in conjunction with primary treatment may remove consistently, when properly designed and operated, 90 to 95 percent of the B.O.D. and suspended solids in the raw sewage and whereas at one time it was considered to be a delicate process, we now know it to be a most rugged process when the design and operation are properly carried out. Its big advantage over the trickling filter process already discussed with you by Mr. Tredgett is the fact that through cold or hot weather it can carry out its treatment equally as well without any material variation in its efficiency provided proper steps are taken to adjust the environmental conditions of the activated sludge to the sewage load and temperature of the particular season.

Recent Design Factors in Activated Sludge

The efficiency of the activated sludge process therefore, may be considered to be the relation of the removal of pollutional matter to the plant resources used to produce the result. B.O.D. reduction as previously indicated is generally still used as the most important single indicator of activated sludge plant operation since its reduction is generally accompanied by an equal reduction in suspended solids.

It has been indicated that until recently the main facts to be taken into account by the designers of activated sludge plants were as follows:

1. B.O.D. loading per unit volume of aeration tank.
2. Aeration contact period.
3. Suspended solids concentration.
4. Quantity of air required.
5. Final settling tank capacity.
6. Character and quantity of the return sludge.

Under (1), B.O.D. loading per unit volume of aerator, a figure of 15 to 50 pounds of B.O.D. per thousand cubic feet with an average of 30 pounds of B.O.D. per thousand cubic feet was normally used in the design of major plants and is still used by many designers.

Under (2), the actual aeration contact time or the time of contact between sludge and sewage, could never be exactly determined, and it was generally related to a detention time equal to 4 to 8 hours for sewage flow plus a nominal allowance of 25 percent of the sewage flow in return sludge volume.

Under (3), the concentration of suspended solids in the mixed liquor has definitely been established as a prime factor in plant efficiencies. They have normally varied from 1,000 to 2,000 p.p.m. with 1500 p.p.m. being average. Related to this has been the Mohlman sludge index which has been defined as the volume of the solids in the aeration tank settling in a litre graduate in 30 minutes divided by the total weight of suspended solids in p.p.m. contained in the aerator. The index is a measure of the settleability of the sludge and has been used for some years as a very successful indicator of the condition of the sludge. Normally it runs between 75 to 100 in percentage form and if a plant is carrying a concentration of mixed liquor solids of about 1500 p.p.m. the settling test should indicate about 10 percent or 100 millilitres in 1 litre, in order that the sludge index could approximate 70.

Under (4), air was generally supplied at the rate of 0.5 to 2.0 cubic feet per gallon of sewage depending on strength of the sewage. We know that about 40 to 65 p.p.m. of air are required in the initial stages of the aeration tanks per thousand p.p.m. of suspended solids being carried therein to satisfy air requirements and maintain at least 1 p.p.m. dissolved oxygen and that this demand diminishes to about 20 p.p.m. per thousand p.p.m. tank solids as we reach the effluent end of the tank. It is for this reason that tapered aeration has, especially in small plants, been introduced in order that the oxygen may be introduced in a greater quantity at the inlet of the aeration tank and reduced to some extent as the sewage travels through the tank to maintain the dissolved oxygen at more or less constant values. One should, however, take into account in tapered aeration that the air discharged to the sewage in any particular section of the tank should not be less than that necessary to create sufficient cross velocities of at least two feet per second to prevent the settling of sewage on the tank bottom.

Under (5), if you will bear with me I shall leave the discussion of this point for some few minutes.

Under (6), the rate of sludge return was previously set at 10 to 30 percent of sewage flow. Actually it bears no relation to the sewage flow except as far as the hydraulics are concerned and today we are simply concerned with maintaining the solids at the least level possible in the final settling tanks and therefore carrying out the return of sludge at a rate satisfactory to prevent the formation of a high oxygen demand in the sludge through over-retention in the final settling tanks. We are, therefore, interested in a sludge of excellent quality which has little or no oxygen demand and which has good settleability.

Generally speaking the design of aeration tanks today involves limiting the tank's cross section between a ratio of 2 to 1 and 3 to 1, as far as width to depth are concerned with the maximum depth not generally exceeding 15 feet and a ratio of as high as 20 to 1 to 5 to 1 as far as length to width are concerned. This naturally applies to the diffused air type of an aeration tank which is by far the most common on this continent. Mechanical aeration tanks employing propeller type cones which discharge the sewage from depth onto the tank surface causing rapid assimilation of dissolved oxygen from the air have been for some time used on this continent but not to the extent they have been used in Europe and Great Britain. Recently, however, the development of an improved type of mechanical aerator known as the Simplex high intensity cone has led us to believe that this matter of mechanical aeration is worthy of greater consideration, that it compares equally in first cost to our diffused air plants and may possibly even be cheaper in operation than the equipment in these plants. Certainly if the design is of any size the consideration of mechanical aeration has now reached the stage following the plant scale test at Manchester, England, that we must consider it closely.

All diffused air systems now being installed on this continent are of generally the spiral flow type. The air is discharged at depth in the sewage at one side of the aerator either through the original ceramic plate type installation which despite all reports to the contrary is still the cheapest and easiest maintained system of air diffusion available to us in the design of larger plants. Unfortunately a plate system is not extremely flexible if you do desire to change the air quantities or the rates at which air is applied in different sections of the tank. If such is desired ceramic type tubes are available which can be screwed into longitudinal type headers running along the bottom of the tank or can be fed from headers on the tank walls through down pipes to short longitudinal sections of header probably 12 to 18 feet in length. The tube spacing is varied of course depending on air requirements and is kept at a maximum of probably 24 inches to insure against settling out of the sewage and low cross velocities. Tube arrangements on swing

diffusers are also available and in this instance the manufacturer of this equipment has advocated the use of stainless steel perforated diffuser tubes wound with saran cord, a much lighter tube better adapted to the swing diffuser system but a tube which has again given in many instances considerable operating problems due to the fact that unless it is operated at its rated capacity fairly continuously it tends to slacken and the cord unravel providing a real operating headache and a considerable maintenance cost. Many other types of diffuser systems are available to the plant designer. I feel that the swing diffuser system is most applicable to the smaller plants where to take a tank out of service to service tubes or plates would require the loss of possibly as much as 50 percent of the plant capacity, something which in warm summer months certainly could not be tolerated. On this basis swing diffusers deserve real consideration for such plants because they permit a proper maintenance programme to be carried out without the loss of any material capacity at the plant. As to whether they are necessary in larger plants where they may be in sufficient number for their maintenance to become a problem, that is a question for the designer to determine in view of the specific plant in question. A new type of diffuser system is now on the market which was originally developed by Dr. Hatfield in Illinois and finally put on a full scale plant basis by Kraus in Peoria, Illinois in which a perforated type pipe header is immersed in the sewage on the opposite side to the plates or tubes. This pipe header is only immersed to a depth of possibly half or one-third the water depth in the aeration tank and serves to cause a counter current flow and a highly turbulent condition on the surface of the aeration tank resulting in considerable increase in the amount of oxygen capable of absorption by the sewage from the air, and therefore resulting ultimately in a lower amount of air required to be compressed by the blowers in the plant and some saving in the plant operation.

Normally we rate diffuser media of the ceramic type at about 3.5 cubic feet a minute per square foot of surface area. Actually tests of Chicago have indicated quite clearly that under normal conditions where air prior to compression is properly cleaned that a plate should be capable of passing approximately 10,000,000 cubic feet per square foot of surface before its life has expired or before measures must be taken to restore its capacity. Actually you can see therefore, that if a plate were to be operated at the rate of 2 cubic feet per minute its life would be 1½ times as long as a plate that was operated at normal rating of 3.5 c.f.m. We feel that 2 cubic feet per minute is about the minimum rating that can be tolerated since anything less is liable to result in severe clogging at the tube at an early date, due to insufficient air velocities. Certainly the maintenance of diffuser tubes is a serious problem in the operation of an activated sludge plant, no matter what its size, and the new

development by one manufacturer of pipe headers running along the base of the tank with perforated spargers discharging air laterally into the tank at depth is most significant. Such a system does not require the heavy maintenance that a ceramic type plate or system tube does. However, it remains to be seen whether it provides an efficient means of discharging air into the sewage. Experiments to date in a large Los Angeles plant have indicated that such is the case, although experiments conducted on simple perforated pipe diffuser systems have generally indicated them to be highly inefficient when compared with air consumption at diffuser type plants.

Air is generally supplied at the modern diffused air plant through three alternative types of equipment. One is a reciprocating or piston type compressor or as an alternative under this type we have the rotary positive displacement type represented by Rootes or Standardaire manufacture. These types of units do not vary their capacity with build up of pressure through plate or tube clogging and will continue to deliver at rated capacity provided their driver has sufficient power to overcome the pressure developed. The discharge of these units however, can only be regulated by a change in their speeds and the throttling of their valves will have no effect in changing their discharge but may of course cause the driver to kick out because of overload. On the other hand a centrifugal type blower can be regulated in its discharge through the throttling of its discharge valve. Of course, as pressure increases through the clogging of tubes its capacity drops off and generally under such instances the sewage load itself is increasing so that such equipment loses capacity at the very time it is required most. The reciprocating or positive displacement types have a considerable vibration in their delivery which can be dissipated to some extent through the proper use of snubbers on their suction and discharge piping. Centrifugal blowers generally have a high pitched squeal or howl and must be operated at 1750 rpm or better and are difficult to control in noise. The reciprocating or positive displacement type, especially the latter, when operated at a low speed are generally not objectionable in noise and are for that reason to be preferred in areas where built up housing or development closely encircles the plant site.

In passing I have referred to a discussion to take place now on final settling tanks. Such tanks are furnished for activated sludge service in circular, square or rectangular shape, the rectangular tanks generally employing a chain drag collector system with flights scraping the sludge from the effluent end of the tank to a hopper at its entry end, although some designers prefer to operate their mechanism in reverse direction on activated sludge for reasons of density currents. The square or circular tanks are generally equipped

with circular centre supported plow type clarifiers, with end expansion pieces being adapted to the equipment for cleaning the corners of square tanks.

At one time it was considered that to design these tanks properly should require a two and one-half hour retention time for sewage flow plus return sludge flow. Later revisions indicated that a surface overflow rate based on an average sewage flow was all that was necessary to properly design these tanks and a rate of approximately 900 Imperial gallons per square foot per day was considered adequate. Ultimately however, through investigations carried out by the Sanitary District of Chicago and further confirmed by the Department of Public Works of the City of New York, it was shown that density currents were the main factor to be considered in the proper design of final settling tanks. These investigations indicated that the mixed liquor flowing from the aerator to the final settling tank entered the tank as an intimate suspension of flocculant solids acting as a liquid with a density greater than that of water which caused the mixed liquor to plunge to the bottom of the tank and flow along the bottom until deflected upward by the end wall of the tank, thereby inducing a counter current in the upper levels back toward the influent end of the tank. This effect however, was found to exist only above the sludge blanket level as the latter appeared unaffected by the current, apparently because of its compactness. Naturally if weirs happen to be located at the point where such currents struck the surface after being deflected upwards by the tank walls, considerable solid content would be discharged over such weirs resulting in a deleterious effect on the purity of the effluent from the plant. From the studies carried out by Norval Anderson, of the Sanitary District of Chicago, it was indicated that where circular or square tanks were involved the radius of the tank should not exceed the side water depth of the tank by more than five times and that for rectangular tanks where the velocity was better distributed, the flow length should not exceed the depth by more than seven times, and that the depth of water below the effluent weirs should be more than 10 feet and preferably be more than 12 feet. If such conditions were not practical, then special precautions must be taken on weir design. Further these studies indicated that tanks should be so designed as to have a weir overflow rate of not more than 15,000 gallons per day per lineal foot of weir and a surface overflow rate as previously indicated of not more than 900 gallons per square foot per day. Further experience and operation has indicated, as already pointed out, that sludge should not be carried at a depth greater than one foot in the final settling tanks and should not be held in such tanks for more than one hour and preferably 30 minutes. In other words, the two and one-half hour retention time we have so long heard about is only necessary to create sufficiently quiescent conditions to settle the sludge readily in approximately 30 minutes to one hour. It is interesting to note in studying the different types of

mechanisms available for the collection of sludge in final settling tanks that there is a type on the market adapted to circular or square tanks which is composed of a number of nozzles sweeping around the tank in a circular fashion which are held approximately one foot off the tank floor and draw the sludge much as a vacuum would into a rotary pipe arm by the suction of the return sludge pump. This has the benefit of preventing sludge build-up ahead of the blades of the collector mechanism, a fact which in our opinion requires considerable thought before drag chain type collectors are employed as final tank collectors despite the experience of the City of New York to the contrary. Our experience has been that such collectors tend to build up the sludge over a long drag length with the result that at the influent end of the tank considerable pin-pointing of sludge can be seen at the tank surface.

New Concepts in Activated Sludge Design

We have now discussed the theory and standard basis of the design of activated sludge plants. I think it is now time that we reviewed and discussed the new concepts in the design of such plants. Since 1946 the United States Government through grants issued by its Public Health Service have considerably increased the amount of research work being carried out in the field of activated sludge, and today we have after such intensive research been able to finally reach a more knowledgeable basis in the design of the process and have finally been able to determine, we believe, the common dominator for activated sludge plant design and operation. This new concept, or as the New York Engineers call it, the load to culture relationship, relates B.O.D. loading to suspended solids carried in the aeration tank and to the air supplied and relates the rate of return sludge to the sludge index. It recognizes the sludge load being carried in the aeration tanks as being a basic part of the treatment and the selection of its optimum volume in relation to the organic load applied as being the real basis for design. Such concept also encompasses the phase of sludge re-aeration as an important aid to activated sludge operation. We think therefore, that we have finally arrived at a basis on which we can compare the operation of plants from one town to the next through the relation of the applied B.O.D. to the suspended solids contained in the aeration system. We wish to point out however, that certain variations still will exist. We know that the character of the B.O.D. varies considerably depending on how it is constituted. Whether carbohydrates, proteins and fats are evenly balanced or any one predominates can basically change the picture but still we believe we have arrived at a point from which it will not take too long to fully solve the process. In view of such new concepts therefore, it is worthwhile reviewing the method of design as it has now been developed, such method to a large extent succeeding the more

empirical methods previously outlined.

As I have already mentioned, the basis of proper activated sludge plant design and operation is the balance between clarification or adsorption and oxidation. If oxidation lags behind adsorption the settleability of the sludge deteriorates and bulking is encountered with the result that although clarification is excellent the floc may commence to flow over the secondary tank weirs. If oxidation lags still farther behind the sludge will lose much of its clarifying power although its settleability may improve and become even better than that of activated sludge. Under such conditions we get a modified aeration type of treatment being formed which is not as efficient as activated sludge providing only about 75 percent removal of B.O.D. and suspended solids but which is perfectly adequate for those areas of population where effluents can be discharged to receiving bodies having adequate capacity for proper dilution of the plant effluent.

On the other hand, if oxidation materially exceeds clarification, much of the sludge will be destroyed, by what we might call "wet combustion" or over-oxidation and the remaining floc particles become very small and compact. Such a sludge does not produce a sparkling clear effluent although nitrification may be high. Apparently the sludge is partially broken up into pin-point floc by reason of such over-oxidation. These particles do not settle readily in final clarifiers even though the main body of the sludge has a low Mohlman index. Further, as a result of such over-nitrification, evidence of the release of gaseous nitrogen from the final tank contents may appear and intermittently chunks of sludge may suddenly rise to the surface of the final tanks. Such will result from the action of bacteria called de-nitrifiers which actually commence to de-oxidize the nitrates back to nitrites in the reverse of the nitrogen cycle. Such de-nitrifying bacteria actually thrive in the sludge of the final settling tanks and can wholly destroy a most satisfactory process.

To maintain the proper adsorption - oxidation balance the operator may only vary the solids in the mixed liquor, the rate of return sludge and/or the rate of air discharged to the aeration tanks, whereas the designer may also vary both the volume of the aerators and final settling tanks. He therefore, has the opportunity to properly provide the flexibility that a plant under today's system of operation requires.

The results of experimentation and plant operation carried out on the new concepts of activated sludge have now been properly summarized by Haseltine and others working on the Committee of the Sanitary Engineering Division of the American Society of Civil Engineers now preparing a publication on the design of activated sludge plants, and the results of their

work as far as aerator design is concerned are best outlined in that publication which will soon be available for distribution. In this paper they have indicated that a loading of 15 to 50 pounds of B.O.D. per 100 pounds of tank solids is a normal design when a removal of 90 percent or better in B.O.D. and suspended solids is desired and if the adsorption oxidation balance is to be maintained. It is recommended where highly skilled operation is carried out in larger plants that this loading be in the range of 30 to 40 pounds of B.O.D. but that the loading be reduced to 20 to 30 pounds of B.O.D. for smaller plants where facilities and instrumentation are not sufficiently extensive to permit the operator to carry out a delicate balance of operation.

According to such bases, if it was required to design a plant to treat one million gallons of sewage per day having a concentration in B.O.D. of 200 p.p.m. in the influent to the aerator, the B.O.D. input to the aeration tanks would be therefore, 2,000 pounds in 24 hours. If the B.O.D. loading is limited to 25 pounds per 100 pounds of tank solids then the total solids to be provided in the tank would be 8,000 pounds. These solids might be carried in the aeration tanks or a portion of them might be carried in a separate sludge re-aeration tank. The volume of the tanks required would depend on the concentration of the solids in them.

Without separate sludge re-aeration a 300,000 gallon aeration tank with a concentration of 2700 p.p.m. solids would be required, or alternatively a 600,000 gallon aeration tank with a lower concentration of 1350 p.p.m. solids would be necessary. If however, separate sludge re-aeration were installed with a maximum solid content of 5,000 p.p.m. carried in a 100,000 gallon tank then an aeration tank capacity of only 150,000 gallons with 2,000 p.p.m. solids in the mixed liquor would be required.

Under the old loading basis of 30 pounds of B.O.D. applied per thousand cubic feet of aeration tank these three designs would compare as follows: the 300,000 gallon plant would have a loading of 41 pounds of B.O.D. per 1,000 cubic feet of tank, the 600,000 gallon plant would have a loading of 20 pounds B.O.D. per 1,000 cubic feet of tank, and the sludge re-aeration plant would have a loading of 50 pounds of B.O.D. applied per 1,000 cubic feet of tank. This clearly illustrates the fallacy of setting up volumetric B.O.D. loading without considering solids concentration. It also shows the vast saving of space that can be accomplished through the use of sludge re-aeration.

No doubt there are limiting concentrations of solids that may be carried in an aeration tank and sludge re-aeration tanks. However, if the rate of sludge return is adequate to prevent undue accumulations of sludge in the final settling

tanks during periods of high index, that is periods during the day when the B.O.D. loading or suspended solids loading is considerably increased through a high organic increase in load, then the concentration in either the aeration or re-aeration tank will not become excessive.

An index of 100 as already mentioned is generally a average but it may range from 40 to 400 during the day. It is impossible of course, to maintain a constant B.O.D. to solids relationship during the variations of the day and therefore the design should permit proper operation under the worst index conditions, in other words, the return sludge concentration should never be permitted to exceed the sludge index expressed as a percent solids.

If we provide return sludge capacities sufficient to prevent the Mohlman index exceeding the return sludge concentration we would require for example one, that is the concentration of 2700 p.p.m., that a capacity in return sludge of 125 percent of the sewage flow be installed and that for two, a capacity of 35 percent of the sewage flow be installed and that three employing sludge re-aeration, a capacity of 70 percent of the sewage flow be installed. It is probably out of reason to require that provision in return sludge flow for anything in excess of 100 percent of the sewage flow be installed in modern day plants but designers today should provide for such flow especially in small plants and for flows of at least 60 to 75 percent of the daily average flow in the larger plants in order to accommodate this new concept of design. If the foregoing procedure is followed the total volume of aeration and sludge re-aeration tanks will, as previously stressed, be determined by (a) the B.O.D. to solid loading, (b) the maximum sludge index and (c) the capacity of the return sludge facilities.

We should provide from 60 to 90 minutes for settled sewage and return sludge contact time, in other words, for clarification to take place under average conditions, but the remainder of the time if desired could be provided in re-aeration. Recently this process was patented under the name of "bioadsorption". Fortunately, it has been proved since that such a process could not be patented because it has been long since established and therefore is open to use by anyone without the payment of patent rights. Actually as many of you well know, plants established as early as 1929 provided sludge re-aeration facilities. Unfortunately we did not realize that such facilities should be as extensive as we now do, that they should carry concentrations as high as we now recognize and that provision be installed in them to supply air at extremely high rates to maintain the biological activity at the high degree required in sludge re-aeration tanks. Some may be quite concerned at the high rates of return. We should however, remember that this is similar to the practice carried out in high rate trickling

filter design as already described to you by Mr. Tredgett. With 100 percent return the mixed liquor period in the aeration tanks will be just one-half of what the sewage aeration period would be with no return. However, all sewage on the average would pass through the aeration tank twice rather than once so that the effective aeration period is actually unchanged. We also must recognize that sludge re-aeration has considerable advantage over the older conventional systems due mainly to its flexible arrangement and the smaller space that it will occupy but it is admitted that it will require a more complex plant layout. Actually there appears to be, through experience gained at Peoria, Illinois, considerable reason to believe that 90 percent purification in activated sludge plants can be carried out through the use of sludge re-aeration tanks by using loadings as high as 60 pounds of B.O.D. per 100 pounds of tanks solids.

Air requirements when related to B.O.D. to solid loadings represent a relatively static 520 to 580 cubic feet per pound of B.O.D. removed, when the loadings exceed 30 pounds B.O.D. per 100 pounds of solids. When loadings are less than this however, air requirements rise substantially to over 1000 cubic feet per pound of B.O.D. removed when loadings become less than 20 pounds of B.O.D. per 100 pounds of tank solids. Under the latter conditions of operation apparently oxidation materially exceeds adsorption so that much air is wasted through nitrification, while under the former condition the two actions are practically in balance and air requirements are steady and just sufficient to maintain proper dissolved oxygen in the tanks.

Operation of Activated Sludge Plants

We have discussed the basis of design both past and present for activated sludge plants. We have in this pointed out the fact of maintaining the essential clarification - oxidation balance. We have pointed out that when clarification exceeds oxidation, bulking and poor settling sludge results and that when oxidation exceeds clarification pin-point floc and nitrification will result with ultimately de-nitrification occurring in the final tanks. It would not therefore, appear wise for us to review the various ills that may befall an activated sludge plant as far as you, the operator, are concerned. We of course ask the question, what causes oxidation to be greater than adsorption and we feel it can be answered in three ways:

(1) Through ever-retention in the aeration tanks. This especially occurs in new plants that have not picked up the design load and will not for some period of time. The obvious answer to overcome such a condition is cut out an aeration tank.

(2) Through over-capacity in the air supply. This again may occur in new plants or even plants long established which have already accepted their design load. Especially is it true in the latter instance during the periods of the day when low organic loads are experienced. In such instances it is wise to reduce the air supply, if possible.

(3) Through over-weak sewage. At certain plants that the writer knows of, especially those designed for the Air Force and the Army, where the particular encampment may be operating at an establishment of only one-third or one-quarter of the design population, the sewage becomes very weak as it is comprised of more infiltration water than sewage. Under such instances oxidation greatly exceeds adsorption and even when capacity is reduced by the taking out of an aeration tank we may still be faced with the treating of an exceptionally weak sewage. In such instances it may be well to make arrangements to add digested sludge to the inflow to permit the sewage to be raised in strength to a sufficient point where it can be properly treated.

Actually, however, we only wish that we were faced with more problems of oxidation exceeding clarification. Normally we are concerned with overload in which instance clarification exceeds adsorption, and this to most operators is the most exasperating problem of all, because there appears to be little that can be done to solve the problem short of plant expansion. Today however, we feel that, had greater flexibility been incorporated in the original design, something could be done about the problem.

We have outlined here some of the problems that can occur with relation to clarification exceeding adsorption and describe means by which such problems might be overcome if such flexibility were available to permit the remedial measures to be carried out.

(1) The lack of sufficient air in the aerator and the fact that dissolved oxygen is not being maintained in certain sections of the aerator. If the air supply cannot be increased in the plant to meet this requirement then the solids must be decreased to cut down biological activity because we do realize that the air requirement is a straight function of the biological activity and if we wish to carry a high solids load we must be prepared to submit such solid loading to a high rate of air supply.

(2) Germicidal wastes in the settled sewage. Such wastes may cause excess acidity or alkalinity in the activated sludge resulting in bacterial retardation and the slowing down of the activity in the aerator. To overcome this problem the waste must be neutralized by adding lime in the case of an acid or an acid in the case of a base, However, in the case of wastes such as phenols or chrome reaching the plant we must admit that these are generally bacteriacidal and they must be excluded from the sewer if we desire to carry on the process as designed.

(3) Excessive carbon dioxide in the aerator. As we have already pointed out sewage contains much carbon dioxide and the biological activity generates even more. If aeration is not sufficient to overcome and blow off this excess carbon dioxide then lime must be added to neutralize it. Only experimentation will tell if this problem exists and if the lime being added will correct the condition. It does however, frequently occur and it more than frequently is not realized as a problem of any magnitude.

(4) Septic sewage or sludge. This action produces excess CO_2 as already indicated above and other compounds that will retard oxidation. To avoid such a condition if possible do not permit sludge accumulation in the clarifiers and resulting loss in oxygen and chlorinate the return sludge slightly to reduce such septic condition if it does develop. If the sewage is septic by reason of flow entering the plant being held for long periods in the sewers, then obviously the best method of attempting to overcome this condition at the plant would be through pre-aeration and short period settling. Naturally the latter facilities are rarely available in most plants and we can only suggest that if such facilities are not available that re-chlorinating stations be installed in the sewerage system to control septicity in the sewers as the sewage flows to the plant.

(5) Excessive grease content in the sewage. We know that if the grease content in the return sludge is excessive, the sludge particles become coated with grease which prevents intimate contact with the oxygen and bacteria. The only solution for this at the plant would appear to be pre-treatment through aeration and chlorination for grease removal. Actually if the return grease content results from industrial waste in the sewage, then the grease content of this waste should be reduced prior to its discharge to the sewer.

(6) Inadequate aeration period. This problem can possibly be overcome in some instances by converting a portion of the aerator to sludge re-aeration and carrying considerably higher solid concentrations in the available space than had previously been considered necessary. Naturally in doing so larger volumes of air will have to be made available in such space.

(7) The improper balance of carbohydrates to proteins, in the B.O.D. of the influent settled sewage to the aerators. It has now been proved through plant scale operations carried out in this continent that nutrients can be added to the sewage to balance such deficiencies. For instance in the case of a large excess of carbohydrates that might be derived through strong brewing wastes being present in the sewage, digestor liquor containing of course considerable quantities of nitrogen might be added to the influent sewage to the aerator or in instances where packing house wastes represent a large portion of the sewage strength starch could be added to make up the balance between the carbohydrates and the protein.

Routine Tests in Operating an Activated Sludge Plant

We have now had the opportunity of reviewing the theory, design, and basic ills that may befall an activated sludge plant. In order that the plant may be maintained in proper clarification-oxidation balance and its operation may be carried out efficiently certain controls are necessary as follows:

(1) those to regulate aeration,
(2) those to control the amount of sludge, and
(3) those to measure the condition of sludge.

It is well for the operator of the small plant whose facilities are limited to realize how important these controls may be. By such realization it may be within his powers to obtain sufficient equipment to carry out certain of these tests. Actually in none of these instances is the equipment expensive and it serves as a basis for the operator taking a further hand and interest in his work. Under (1) the regulation of aeration, we must say that until recently the dissolved oxygen tests were considered by far the best and perhaps the only logical method of controlling it. So long as the air diffused in the solution exceeds that required by biological activity the situation is in hand. These oxygen requirements are always greatest where the sludge and sewage first mix as already indicated. When

considerable sludge volumes are being handled, the variations in volume and strength of the sewage have little if any effect on the air requirements so that aeration may continue at practically a constant rate. However, when low solids are carried there will be some hourly variations in the oxygen requirements and under these latter conditions and in larger plants the saving in power resulting from intelligent variation in air supply may be sufficient to warrant making dissolved oxygen determinations several times a day. In small plants however, or those carrying a high concentration of sludge one set of determinations per day should be adequate. Preferably these determinations should be carried our approximately six hours after the peak sewage flow reaches the aerators.

The dissolved oxygen determination should be made at various points from inlet to outlet. A trace of oxygen should be indicated at the inlet and from one to two p.p.m. should be shown at the outlet. If nitrification should be required it will be necessary to carry three to six p.p.m. at the outlet of the aerator. Recently however, the dissolved oxygen test has been abandoned by some operators and an oxidation-reduction test substituted. The meter and leads for such a test are actually identical to those required for the pH test and therefore, there would be a twofold use for such a meter. Checks are made through the aerator as in the case of the D.O. tests, but with little time involved, and as long as readings exceed approximately 200 millivolts, the oxidation process is considered stable. When readings commence to lag behind this figure, precautionary measures are indicated and when the reading falls below 100, corrective measures are immediately required.

To balance the oxygen load it is often necessary in small plants with low return rates to taper the aeration as already indicated. Another solution however, is in a recent development at the City of New York of a method of activated sludge aeration known as step-aeration. Under such conditions of operation the air discharged to the aerator is kept constant over its full length and the sewage is distributed at three or four points along the length of the tank, thus levelling out the load. It is also possible to operate at a fairly constant rate of sludge return. Indeed it may be that the simplest form of activated sludge operation ultimately will be shown to be that of step-aeration as developed by the City of New York.

By returning sludge at higher rates the sewage sludge mixtures can often be so diluted as to equalize the oxygen rate requirements through the aerators to some degree and avoid the necessity for carrying out a tapered aeration method of treatment.

Under (2), the amount of sludge present in the mixed liquor is most accurately measured gravimetrically by a suspended solids determination. Originally as previously indicated it was usually measured volumetrically by observing the percentage sludge in a graduate of mixed liquor after a definite standing time. As already described modern practice indicates measurement by both methods to obtain the sludge index as a measure of sludge condition.

Centrifuging is a method of analyzing sludge volume, by spinning a sample at 2500 to 3000 p.p.m. for 2 to 10 minutes and observing the percent by volume of sludge in this one sample. Naturally such a test is a little more accurate than a settling test but it does not compare with the efficiency of the suspended solids test.

The proper amount of solids to be carried in the aerator has already been described. Briefly in summary, typical mixed liquor solids concentrations for normal sewage are probably about as follows:

Conventional nitrifying plants are 3,000 p.p.m. or more.
Conventional non-nitrifying plants are 1,000 to 2500 p.p.m. (diffused air).
Conventional non-nitrifying plants 600 to 1500 p.p.m. (mechanical aeration)

It should be noted here that the serious frothing problem generally related to the increasing use of detergents is more serious in aerators when the solids are carried at levels below 2000 p.p.m. although it may be found to be present in some degree at any solid level. We also should point out that extreme variations in the detergent problem are often not due to the variation in concentration of the detergent but are due to the changing concentrations of grease and fats in the sewage which readily absorb the detergents and can under certain conditions cause the complete disappearance of foaming for short periods of time.

The third control that we have referred to is that for measuring the sludge condition. By far the most common measure of sludge condition is the sludge index. It has already been referred to as a means of measuring the settling characteristics of the sludge. The high index of course, indicates a bulking condition or septic condition in the sludge, Also in those plants where ash and volatile contents may be readily obtained in solids it is well worthwhile keeping check on the volatile content of the return sludge. A rise in the volatile content generally precedes a bulking problem and gives one adequate time to take the necessary precautions. The reciprocal of the Mohlman Index in percentage form represents generally the rate of sludge return required and it is in this form that it can be readily

used by the plant operator in determining the proper rate of sludge return through the day.

As far as further aids to operation are concerned in connection with the activated sludge process we have not mentioned in the preceding discussion the wasting of sludge and the maintaining of sludge concentration in the aerator at a fairly constant level. We might remind you that if possible it is a better programme to waste sludge on a continuous basis to the primary tank than it is to waste it intermittently. Such wasting is a shock to the biological process itself and results in a heavy load being placed on the primary tank. Indeed in larger plants now, it has become well recognized that separate sludge thickening is a better basis for concentrating the sludge prior to discharge to the digesters or to de-watering facilities. Actually where bulking conditions exist, wasting sludge to the primary tanks only results in an increasing overload on the secondary treatment facilities and therefore the formation of a cycle of continuing overload.

In closing the writer does not hesitate to advise the designers of activated sludge plants that flexibility in design is absolutely essential. Operators should not be handcuffed by the fact that they have no knowledge of the return sludge flow, that they do not know the volume of air being delivered to their tanks and that they have no idea of what the settled sewage represents in quantity. Some small type of laboratory should be made available, certainly a lab where dissolved oxygen determinations or O-R potentials can be readily made. As to the operator, if such tools have been provided then he should use them with care and responsibility. If they have not been provided then he should show his ingenuity in attempting to obtain the necessary controls or setting up such other guides as he may find through his own experience are satisfactory in controlling his plant's operation.

The writer wishes to apologize for the length of this paper and the fact that it was not possible to deliver it in its entirety at the time of the meeting, and trusts that those reading it may find some small part will help them in their daily problems.

THE USE OF TRICKLING FILTERS

IN THE

SECONDARY TREATMENT OF SEWAGE

A Paper Prepared For Discussion In The Course

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of

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Earlier in this course, it has been established that the treatment of sanitary sewage is principally a matter of:

(1) Removing the suspended solid matters, and

(2) Introducing oxygen to lower the biochemical oxygen demand (hereinafter referred to as BOD) of the watery waste portion of the sanitary flow.

Simple settling tanks (usually identified as clarifiers) are essential to all sewage treatment plants. When employed alone with no other form of further primary effluent treatment, single settling tanks constitute one of the simplest forms of what is identified as primary treatment. Under normal conditions, primary treatment will produce, generally, suspended solids reductions of approximately 50 to 60 percent, but the overall BOD reduction will rarely exceed 30 percent and, depending on the strength of the sewage, will more likely be in the vicinity of 20 percent. At present, most of the cities on the Grand River in Western Ontario have primary treatment plants. The City of Toronto is served also by primary treatment.

This paper will deal with one of the two most widely accepted methods employed in conjunction with primary treatment to provide secondary treatment, capable in its fullest form of producing overall reductions in suspended solids and BOD in excess of 95 percent.

In its simplest form secondary treatment consists of introducing air to the primary settling tank effluent to produce an environment in which certain organisms which live on the putrescible matter in sewage, can thrive. This process is followed in many cases by further settling and recirculation of portions of the resulting effluent. The two principal forms of secondary treatment referred to above are:

(1) Activated Sludge Process - wherein, by employing air compressors or blowers, air is put into the sewage, and

(2) Trickling Filters - in which (in very loose terms) the sewage is put into the air.

It is proposed to deal with the latter under the following headings:

(1) Existing Trickling Filters
(2) Function
(3) Basic Design
(4) General Construction

(5) Operation

(6) Conclusions

(1) EXISTING TRICKLING FILTERS

In Canada today, approximately 34 municipalities of over 1,000 population are served by some form of trickling filter operation. This represents approximately 30 percent of the municipalities served by Secondary Treatment Plants.

The known municipalities and the populations served at present are as follows:

Population Served	Municipality
1;100	Bolton, Ontario
2;500	Bourlamaque, Quebec
2;700	Brooks, Alta.
6;200	Bowmanville, Ontario
4;000	Cranbrook, B.C.
6;000	Dauphin, Man.
2;800	Delhi, Ontario
1;200	Didsbury, Alta.
9;000	Dundas, Ontario.
1;000	Falconbridge, Ontario
5;300	Georgetown, Ontario
3;000	Gravenhurst, Ontario
2;000	Grimsby Beach, Ontario
2;000	Hagersville, Ontario
2;500	Hanna, Alta.
12;000	Kelowna, B.C.
5;000	Lloydminster, Sask.
2;000	Maple Creek, Sask.
27;000	Moose Jaw, Sask.
2;000	Morden, Man.
3;500	Neepawa, Man.
1;800	Olds, Alta.
47;000	Oshawa; Ontario
80;000	Regina, Sask.
2;500	Sioux Lookout, Ontario
9;000	Swift Current, Sask.
2;500	Tisdale, Sask.
2;000	Uxbridge, Ontario
9;000	Weston; Ontario
1;100	Whitby, Ontario
2;600	Vegresville, Alta.
2,500	Vermilion, Alta.
4,500	Picton, Ontario.

(2) FUNCTION OF A TRICKLING FILTER

A trickling filter consists of a bed of broken stone, slag, or other course material, not less than 3 feet in depth over which a clarified sewage effluent is uniformly applied. The effluent trickling through the filter stone bed forms a bacterial gel which has definite absorbing qualities for colloidal matter and bacteria.

As the trickling filter does not bear the name of any inventor, it is not easy to trace the development of this unit from the first conception of the idea. It is probable that the present day trickling filter is an outgrowth of the slow sand filter used in the purification of water. Certainly the trickling filter is not to be considered a mechanical device for sieving out the solids in sewage, as the openings between the filter stones are large and cannot possibly remove the solids by straining action.

For many years it has been incorrectly stated that "A stream will purify itself after flowing twenty miles." It is true, however, that a polluted stream will purify itself when the distance of flow is adequate and when no new pollution is added. The stones and debris in a stream undergoing purification become coated with slime, indicating that this material is being instrumental in the removal of organic matter from the polluted water. It was probably due to observations on the self-purification of streams and on the clarifying action of water filters that prompted engineers to duplicate nature in the confines of an engineering structure.

The first experimental filters in the United States we built of gravel at the Lawrence Experiment Station of the Massachusetts State Board of Health in 1889. A small experimental filter was built at Madison, Wisconsin, in 1901 and the first municipal installation was made in Atlanta, Georgia, in 1903. Following since these early installations, the trickling filter has won general acceptance and become widely used.

Coarse bar racks, grit chambers, and primary settling or Imhoff tanks have been described as units that remove some of the suspended solids in raw sewage. Solids that remain in suspension after sewage has been retained in a settling tank for an hour or two are very small in size but, pound for pound, the fine solids contribute as much pollution as do the coarser solids that settle out in primary tanks. Sewage also contains dissolved solids that cannot be removed by sedimentation. The organic dissolved solids will decompose when discharged to a stream and will cause a corresponding pollution load. The organic dissolved solids are difficult to remove physically; even chemical coagulation will not remove any of the dissolved solids from sewage.

It is the primary purpose of a trickling filter to remove from sewage the finely divided suspended solids and the dissolved solids which remain after primary settling.

The trickling filter is composed of materials that provide large surface areas on which the micro-organisms may be retained. The organisms are not unlike those generally found in streams where natural purification is taking place; they must be found almost everywhere and the desired growth occurs if sufficient food and proper environment is provided.

Most trickling filters have been constructed of crushed rock, though filters have been made of practically every inert material imaginable. It is reported that there are in existence filters made of tile, coal, tin cans and slag. Many of these materials have operated successfully, so it may be concluded that the surface on which the organisms grow is of no particular importance. Different depths of filter beds have been studied, and common practice has finally led to the use of a bed four to six feet in depth. That depth has been selected by observing the quality of effluent from plants where good results were obtained when treating domestic sewage.

It is the purpose of the stone or other material to provide the surface area on which the micro-organisms can grow. It seems reasonable that the greater the surface area of the media, the more extensive would be the growth of a micro-organism population within a given volume of bed. This means that the smaller the diameter of the medium (such as stone), the greater surface area there will be in the bed.

Proper aeration is very important in the operation of trickling filters for the micro-organisms living on the filter media require oxygen from the air for their existence. Hence, coarse media is imperative and proper bed ventilation essential.

There are two general classifications of trickling filters:

(a) The Standard (or low rate) filter, and

(b) The high rate (more properly defined as the "high-load") filter.

The difference in these two types is basically the rate at which sewage is applied to the surface area. Prior to 1935, standard rate plants were popular; however, high rate filters have predominated since that time. High rate filters employ dosing rates about six times those of standard rate filters or, simply, a high rate filter requires only one-sixth the area formerly provided. The saving in property requirements and the volume of filter media required will be apparent.

Standard rate filters generally employed two inch diameter stone and beds six feet in depth or greater. The beds were intermittently dozed. It was believed necessary to apply sewage to the filter, to allow it to trickle through the stones, and then to provide time for the micro-organisms to consume the food that had been absorbed as the sewage flowed over the stones. However, the diameter of the stones (with their greater surface area) was such that the upper portions of the bed were more effective.

The high rate filter is relatively shallow - 3 to 5 feet; employs 3 to 4 inch stone which provides ample voids for proper bed aeration and permits constant dosing (continual operation). Further, and most important, the high rate filter utilizes the recirculation of some of the plant effluent within the process. Obviously, mixing the filter influent with the plant effluent (lower in BOD) produces a mixture of lower BOD going to the filters. Repeated recycling of the plant effluent obviously lowers the BOD of the filter influent and hence of the filter effluent.

The higher the application rate, the more sewage is put on the surface per unit of time. High application rates are of value in that they keep excess slime and accumulated solids flushed off the stones, and keep spaces between the stones open for free passage of air. This indicates that it would be desirable to have high application rates - but it must be remembered that the micro-organisms must be given time to utilize the food being supplied by the sewage. Thus, there must be a sufficient accumulation of slime to utilize all the polluting material in the sewage.

There is value in having a high rate of sewage application, to keep the openings between the stones flushed clean, and there is value in having an even and continuous rate of application to the filter, to provide sufficient growth of slime. As both objectives can not be achieved at the same time, a compromise must be reached.

The rest of this paper will be dedicated to a discussion of high rate trickling filters.

(3) BASIC DESIGN OF TRICKLING FILTERS:

Characteristic, but not necessarily essential elements of the process involve:

(a) Presedimentation of the sewage before it is applied to the filter;

(b) Clarification of the filter effluent in either the detention tank preceding the filter or in a separate clarifier;

(c) Recirculation of filter effluent, final clarifier effluent, or final clarifier sludge, back to the new incoming feed;

(d) The use of filter beds having stone depths as low as three feet;

(e) The use of two-stage treatment where very strong sewages are encountered, or where a high degree of treatment is desired;

(f) Substantially continuous filter dosing.

One factor having considerable influence on filter performance is the recirculation ratio R, which is defined as the volume of flow recirculated divided by the average 24-hour raw sewage flow Q. Thus, if the raw sewage flow averages 1.5 mgd, the recirculation ratio is $\frac{2.00}{1.5}$ or 1.33.

Typical High Rate Process flow-sheets involve the use of either single-stage or two-stage treatment as follows:

(a) Single-Stage (Intermediate) Treatment

With this flowsheet (shown in Figure 1) an effluent having a quality between that of a primary treatment and a standard trickling filter may be obtained. With normal strength sewage (200-250 p.p.m. BOD), a reduction of about 50% to 60% may be expected where the volume of recirculated flow is equal to at least twice the volume of the new feed to the system. Whether the final effluent should be taken off at the clarifier or the filter depends on the strength of the raw sewage and the recirculation ratio employed. With weak sewage and/or with high recirculation ratios, a better grade effluent may be obtained from the clarifier. With strong sewage and/or low recirculation ratios, the filter effluent should be better.

(b) Single-Stage Complete Treatment

This flow sheet (shown in Figure 2) differs from that of Figure 1 in that the filter effluent is settled in a separate secondary clarifier before being discharged from the system. This flow sheet should produce results on a par with standard trickling filters. It should be noted that this flow sheet involves the return of filter discharge and/or secondary clarifier material. The secondary clarifier material may be effluent, sludge or any combination of the tank contents.

A popular modification of this flow sheet (see Figure 3) involves the recycling of part of the secondary clarifier effluent to the filter while the secondary sludge is recycled to the primary clarifier. With this arrangement both clarifiers may be

of the same size and have the same detention and overflow rate.

With this flowsheet, overall BOD reductions of 75 to 80% may be expected when a normal sewage is being treated and a recirculation ratio of about 2 is maintained.

The Towns of Bowmanville and Cobourg in Ontario are served by plants designed on the modified flowsheet shown in Figure 3. Some representative BOD removal results for these plants are attached hereto.

(c) Two-Stage Treatment Plants employ a secondary clarifier and secondary filter.

Many modifications of this two-stage treatment flowsheet are possible. For example, a separate clarifier may be used for primary settling, final effluent may be recirculated to the raw sewage, etc.

With a normal strength sewage and a recirculation ratio of 1 to 1 in each stage (2:1 overall), this two-stage system should effect an overall reduction in BOD of 90-95%, with the production of a well nitrified effluent, high in dissolved oxygen and low in suspended solid. In this respect this flowsheet may be regarded as producing results the full equivalent of the activated sludge process. The City of Oshawa is served by such a plant.

The following are the most important factors that influence the design and operation of Biofiltration Systems.

(a) BOD loading on the filter (expressed as lbs. BOD/cu. yds. of filter medi/day);
(b) Recirculation ratio (ratio of recirculated to new incoming flow);
(c) Clarifier detention and overflow rate.

Of secondary importance are dosing rates on the filter, method and continuity of application of the sewage to the filter, and design of the filter bed as to selection of filter media and provision for adequate ventilation. Within limits, the depth of the filter bed apparently has little effect, 6 to 8 foot beds giving little improvements over shallow beds 3 to 4 feet in depth.

With increasing strength a greater amount of BOD per unit volume of filter medium will be removed. A common design basis for filters is 1.5 to 2.0 lbs. of BOD per cubic yard of stone per day. Assuming the depth of the bed and determining the cubic measurement from

the above, the designer obtains the area of stone required. The dosing rate (number of million gallons per acre per day) is established automatically thereby. Provided this rate does not fall below 4 to 8 mgpd and does not exceed 100 to 125 mgpd, this factor appears to have little effect on the process. The purpose of maintaining more than the lower rate is to aid in preventing the accumulation of solids in the filter bed. Another object is to keep the surface wetted more or less continuously, and so prevent the propagation of filter flies. The maximum rate must not be exceeded; otherwise the filter bed will be flooded.

Normally, a plant design should allow for minimum recirculation ratios, - but for stronger sewages or increased reductions, proportionately high ratios should be used. With all types of plants, the higher the recirculation ratio the better the overall results obtained.

Clarifiers in trickling filter plants should be rated on overflow rates as well as on detention period. The former is by far the most important factor. Both overflow rates and detentions should be based on the total flow to the clarifiers, including the recirculated flow. In general, within limits the greater the recirculation ratio the higher are the overflow rates and the lower are the detention periods that may be used without adversely affecting results.

(4) GENERAL CONSTRUCTION OF A TRICKLING FILTER

Most modern trickling filters are circular in shape, generally possessing reinforced concrete w alls and a floor sloping to a centre drain flume. Underdrains are placed atop the concrete floor. Many varieties of underdrains are in use, but in Canada vitrified clay tiles seem most popular. The underdrains conducted the sewage flow (that has percolated through the filter media) to the drain flume, from where the flow is recirculated to the process.

The filter media may be crushed rock, slag or specially manufactured material. The media should be resistant to spalling or flaking, but relatively insoluable in sewage, and free from dust, clay, sand loam, organic or other impurities. The media should be approximately cubical in shape. Slag media should be free from iron. The writer suggests media of 3 to 4 inch diameter with $2\frac{1}{2}$ inch diameter a minimum size.

Self propelled rotating devices are provided to ensure uniform distribution of the sewage influent over the whole surface area of the bed. The distributor mechanism consists of a central ball bearing turntable to which are attached radial arms, usually supported by guy rods from the top of a tubular centre column. A base casting is securely bolted on a hollow concrete pier into which the feed pipe discharges. The turntable top is essentially a hollow well arranged to

distribute the flow properly to the arms. In one manufacturer's equipment the turntable contains a mercury seal to prevent escape of sewage under all normal operating conditions. In case the seal is blown because of excessive head, the mercury becomes trapped in a special compartment while the sewage flows out through openings in the turntable base without danger of getting into the bearing. The ends of distributing arms are equipped to permit flushing while the machine is operating.

The sewage effluent flows through the feed pipe, up the centre pier into the distributing well then into the arms and out of the orifices. The resulting rotation of the arms spreads the sewage uniformly over the entire surface of the filter bed so that every square yard of filter stone is sprayedwith substantially the same quantity of clarifier effluent. The number and sizes of orifices in the arms are determined by the expected range of flow and available head.

There are at leawt three types of high rate filters and distributor mechanisms on the market: "Bio-filter" (Dorr-Oliver-Long), "Aero-filter" (Yeoman Bros.) and "Accelo-filter" (Infilco), while some other firms, such as Pacific Flush Tank sell distributors only. The principal distinguishing feature of each company's filter system and distributor is the type of recirculation employed. Each firm has patented a flow sheet embodying slightly different types of recirculation, which type of operation should be observed when the company's distributor mechanism is employed.

(5) TRICKLING FILTER OPERATION

Operation of a trickling filter is mainly concerned with the following:

(a) Lubrication
(b) Distributor Maintenance
(c) Effect of Temperature
(d) Prevention of Ponding
(e) Prevention of Fly Nuisance

(A) Lubrication

As the filter distributor is a simple mechanism hydraulically driven (in a manner similar to a garden sprinkler), the only lubrication required is an oil bath in which the main ball bearing race operates. Low viscosity oil (about SAE 10) with rust inhibitive properties is recommended by most equipment suppliers, and their instructions should be followed strictly with respect to the frequency of lubrication, etc.

(B) Distributor Maintenance

The need for good distribution of sewage over the filter has been emphasized.

No matter how well sewage is screened and settled, some material of large size will pass through the system and lodge in the orifices or nozzles of the distribution mechanism. Nozzles should be cleaned regularly, so that they never become clogged.

Rotary distributors should be so well balanced and lubricated that they will move as soon as sewage starts to flow from the openings in the arms of the mechanisms. Sometimes growths of slime develop on the distributor arms deflecting plates, and the result is that sewage is not evenly distributed over the bed. In such cases, slime should be brushed from deflecting plates as soon as it appears.

The frequency of cleaning is at the discretion of the operator. It is significant, however, that at one of the most efficiently operating plants (and efficiently operated) in Ontario all distributing arm orifices are wire brushed three times each week.

It is interesting to note that due to temperature changes, it is necessary on large machines to compensate for expansion and contraction of the guy rods supporting the distribution arms. In most cases, the arms should be adjusted so that they will be horizontal at the maximum temperature of the locality where installed. Where the distributor must operate on a very low head, the arms should be as nearly horizontal as possible, at all times. This may require adjustment between winter and summer weather. During extremely cold weather, the elevation at the end of the arm will be about 4" higher than in summer on a 140' diameter distributor and proportionately less on smaller units, if rod adjustments are not changed.

The distributor arms must be level and maintain their level throughout the complete revolution around the filter bed. Adjustments of the arms are explained usually in erection instructions. Efficient operation of any type of mechanism can be attained only after a thorough understanding of its construction.

(C) Effect of Temperature

Temperature affects the activity of micro-organisms, their activity increasing markedly with rising temperature. Therefore, trickling filters can be expect-

ed to operate with more efficiency in the warm weather than they do in cold. In most locations, sewage is well above the freezing temperature - even though ice may sometimes form on the surface of filters. While the average temperature within a filter usually is well above freezing during cold periods, under such operating conditions, however, the environment is not optimum for the growth and feeding of organisms. Filters in cold areas, therefore will not produce as good an effluent in winter as they do in warm months.

In exposed filter beds in Western Canada it was observed that in subzero weather the slime would slough off the stones, which would then remain clean until warmer weather when the growth would re-appear. During prolonged cold spells near zero, the open air filters performed no useful service as the BOD of the primary clarifier and filter were similar.

The popular design trend today is to cover all filters in districts where winters are severely cold; e.g., North of, say, Orillia and the "snow belt" areas of Ontario. Covered filters perform effectively when the air temperature is maintained at 40°F. This has been proved in Western Canada where filters have operated with outside temperature of 30° to -50°F. It is interesting to note that the raw sewage temperature at this plant was 50°F and the plant effluent was 44°F - a drop of only 6°F.

It is suggested that buildings housing filters be adequately ventilated to prevent "fog" forming - air changes every ten minutes being desirable. Further, due consideration should be given the great tendency toward corrosion of equipment and metals in covered filter areas.

Any trouble due to temperature with exposed filters in Southern Ontario is usually attributed to spray freezing in the wind. Some plants erect wooden wind breaks on the side of the tank exposed to the prevailing wind. Rock salt is effectively used at some plants to remove ice film. Generally, it is important to see that no orifice discharge is directed against the tank wall as this encourages growth of ice film.

(D) Prevention of Ponding

Ponding of trickling filters may be a serious problem, and there are numerous causes for sewage to collect on the top of the filter. Sometimes this takes place because care was not used in placing stone in the bed, in such cases many fines (small stones) fill the spaces between large stones and there is no means of carrying away the excess slime that is loosened from the stones. When the spaces between stones become clogged, the sewage cannot flow through the bed to the underdrains.

Surface clogging can sometimes be removed by lightly picking up the surface. Persistent clogging at one spot may indicate sub-surface clogging by dirt and industrial wastes. To remedy this condition the stone may be dug up, washed clean and replaced in the bed. A method of cleaning clogged filter media in place has been developed by Solvent Service, Inc. in which accumulated organic solids are dehydrated by an application of concentrated sulphuric acid, after which the ash-like residue is flushed from the bed. Inhibiting materials are added to the acid to prevent attack on structural elements of the filter bed.

The Town of Gravenhurst floods its filter frequently with a strong solution of HTH and water, allowing it to stand for a brief period. This method should be employed with care so that the very necessary slime is not removed.

The overworked practive of loosening filter stones with crow bars to free clogged beds is not recommended as frequently it does nothing but develop voids through which flows can pass without percolation. Operators confronted with a ponding problem are advised to seek other remedies.

Ponding may develop when the supplied sewage contains a higher-than-normal quantity of organic matter. As a result a large quantity of slime will be formed in proportion to the volume of sewage being applied to the filter. Thus, there is insufficient liquid volume to keep the filter flushed out. In such instances, recirculation of effluent can be very helpful in keeping the filter open and in good operating condition. In some cases, plant operators have temporarily corrected a ponding situation by flushing the surface of the filter with a powerful stream from the nozzle of a fire hose. Clarified sewage effluent has been found to be very satisfactory for this purpose.

(E) Prevention of Fly Nuisance

The psychoda fly which breeds in trickling filters can be a troublesome problem, but apparently has been of minor nuisance in Ontario. Some American plants flood filters with an insecticide solution to combat the problem. Most distributor arms are provided with end orifices to direct a stream on the tank wall to control development of filter fly larvae.

(6) CONCLUSIONS

a) The degree of treatment of sewage may be varied over a wide range by the use of high rate filters.

b) The single-stage process in which one filter and one clarifier is used, will effect BOD reductions of 50-60%.

6) CONCLUSIONS (cont.)

c) The single-stage complete system, using one filter and two clarifiers, will give BOD reductions of 75-80%.

d) In the two-stage system where two filters and two clarifiers are used, BOD reductions of 90-95% may be effected.

e) The chief factors that influence the design and operation of all types of filter plants are BOD loading on the filter, the volume of recirculated flow, and the clarifier overflow rate and detention.

f) The capacity of a filter for removing BOD apparently varies with the strength and characteristics of the applied sewage. With normal strength domestic sewage, 2.0 lbs. of BOD per cu. yd. of filter medium per day appears to be the maximum that can be removed.

g) Recirculation of filter effluent back to the detention tank is of material aid in controlling the degree of purification obtained. In general the recirculation ratio should be increased in proportion to the increase in strength of the raw sewage. In the case of normal strength sewage this ratio should be about 2.0 for single-stage intermediate treatment, 1.5 for single-stage complete treatment and 1.0 for two-stage treatment.

h) The detention tank design becomes increasingly more important as the BOD load on the filters is increased. The average clarifier overflow rate should not exceed 800-1000 gals. per sq. ft. per 24 hours in the case of single-stage plants, and 1200-1500 gals. per sq. ft. per 24 hours in the case of two-stage plants. Average clarifier detentions should not be less than 1.5- 2.0 hours.

i) Within a range of about 8.0 to 100 mgad dozing rates apparently do not affect the action in the filter bed as long as the limiting BOD load is not exceeded.

j) Increasing the filter bed depth beyond 4 ft. gives only a slight improvement in results, and, therefore, is not warranted.

k) Three to four inch diameter filter media is desirable and all media must be clean.

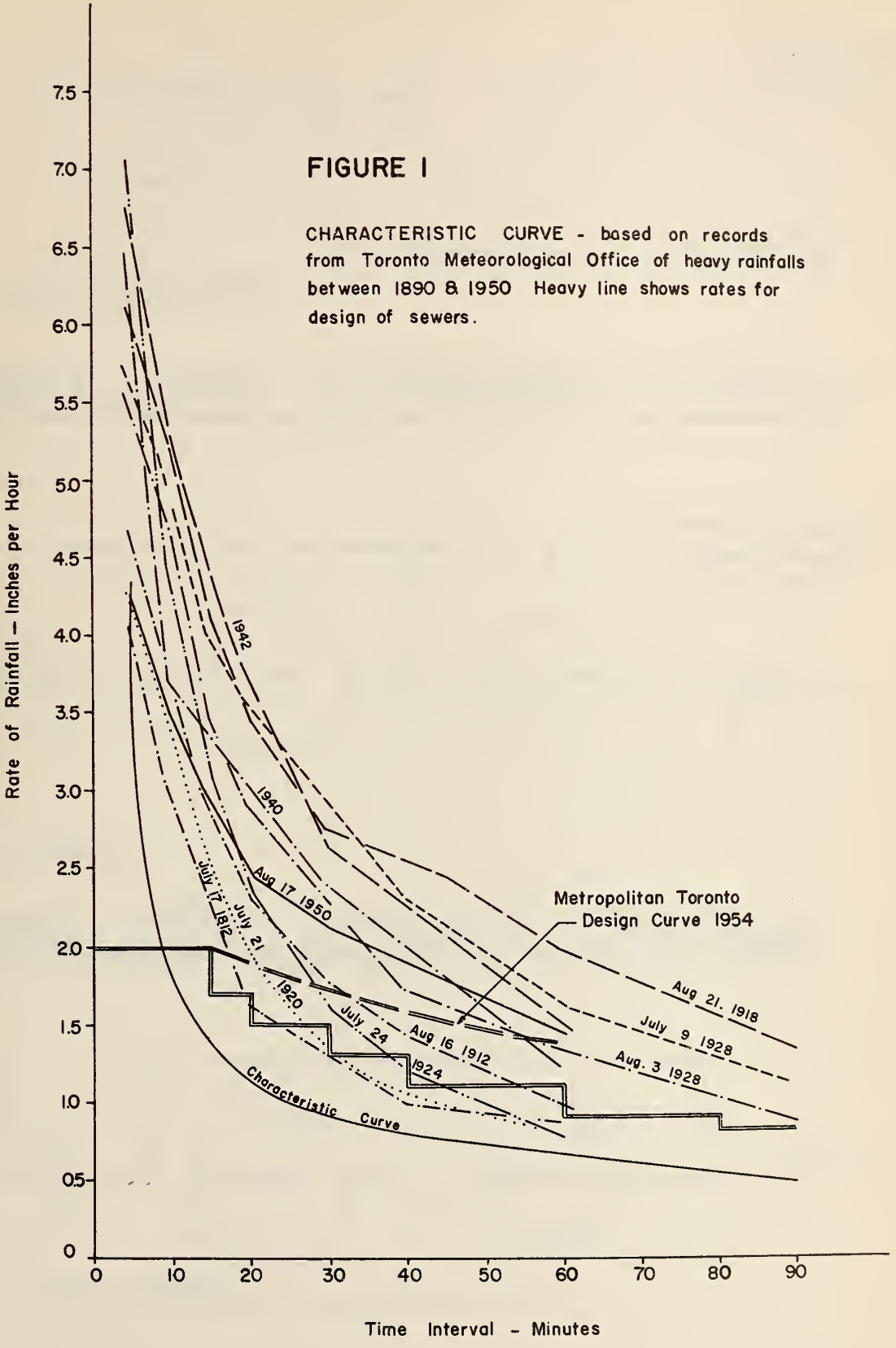
CONCLUSIONS (cont.)

l) Flows to the filter should be applied evenly over the surface of the bed and good bed ventilation is essential.

m) Filters in cold weather areas should be covered, the building maintained at 40^{0}F and ventilation and corrosion protection should be provided.

FIGURE 1

CHARACTERISTIC CURVE - based on records from Toronto Meteorological Office of heavy rainfalls between 1890 & 1950 Heavy line shows rates for design of sewers.



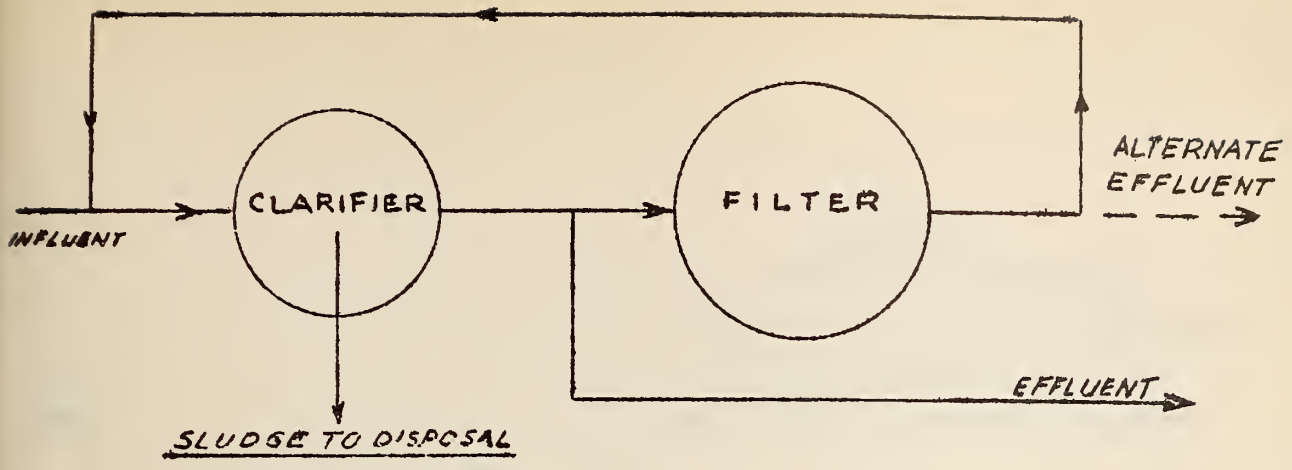


fig 1 SINGLE STAGE - INTERMEDIATE - 50-60% B.O.D.

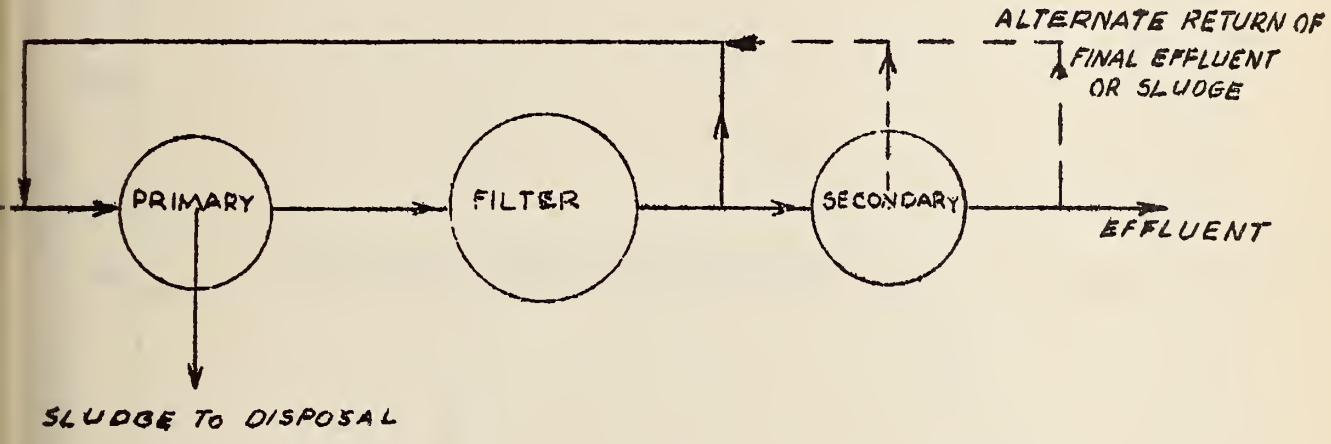


fig 2 SINGLE STAGE - COMPLETE - 75-85% B.O.D.

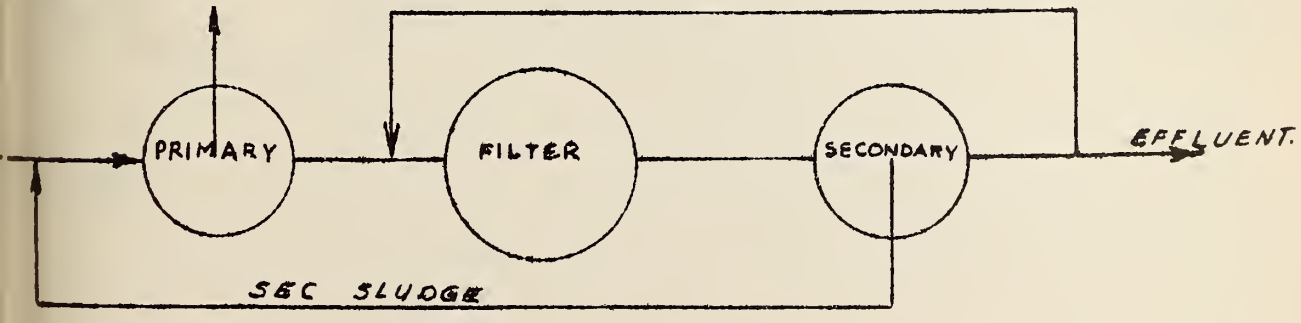
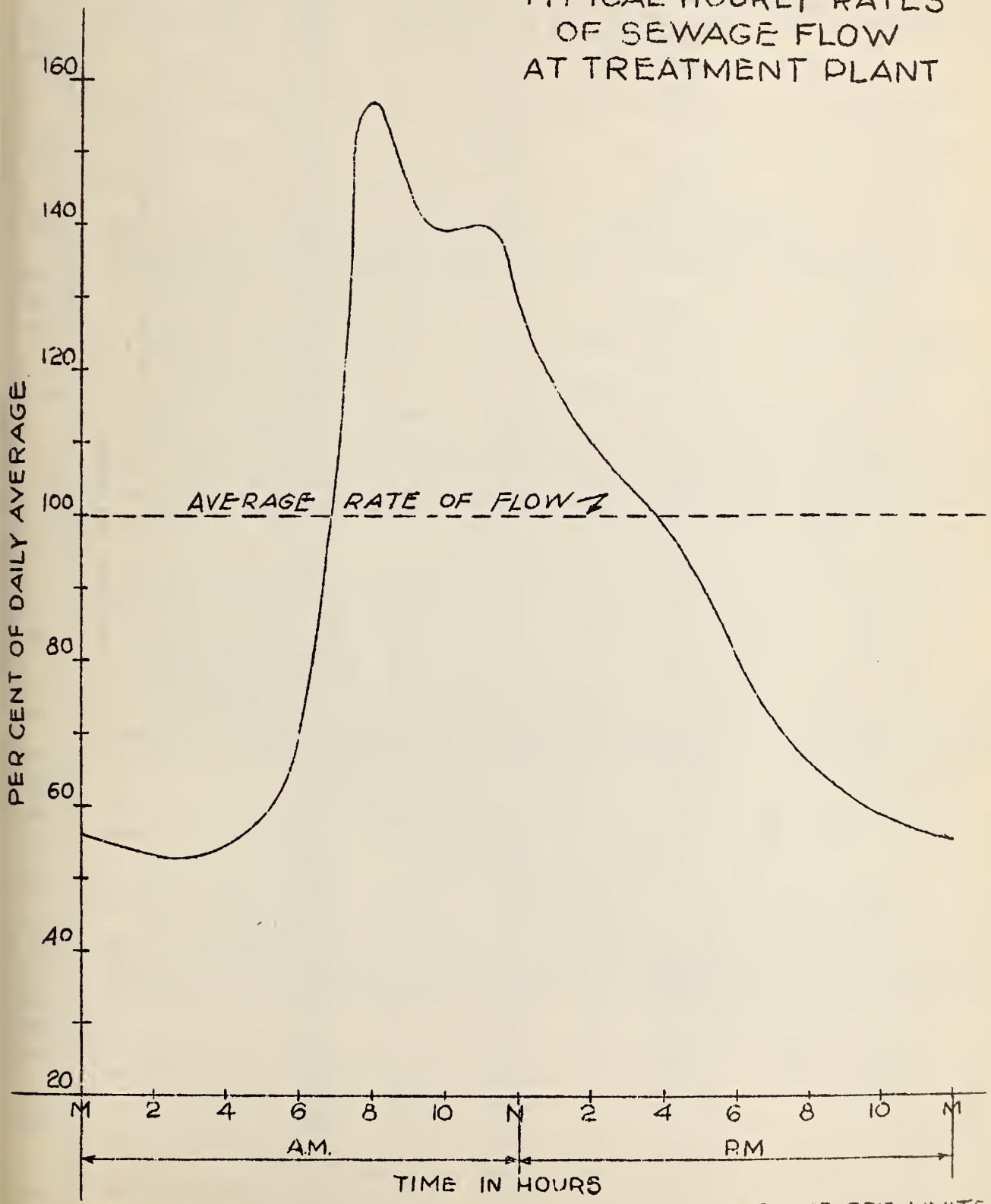


fig 3 SINGLE STAGE - COMPLETE /Alternate/

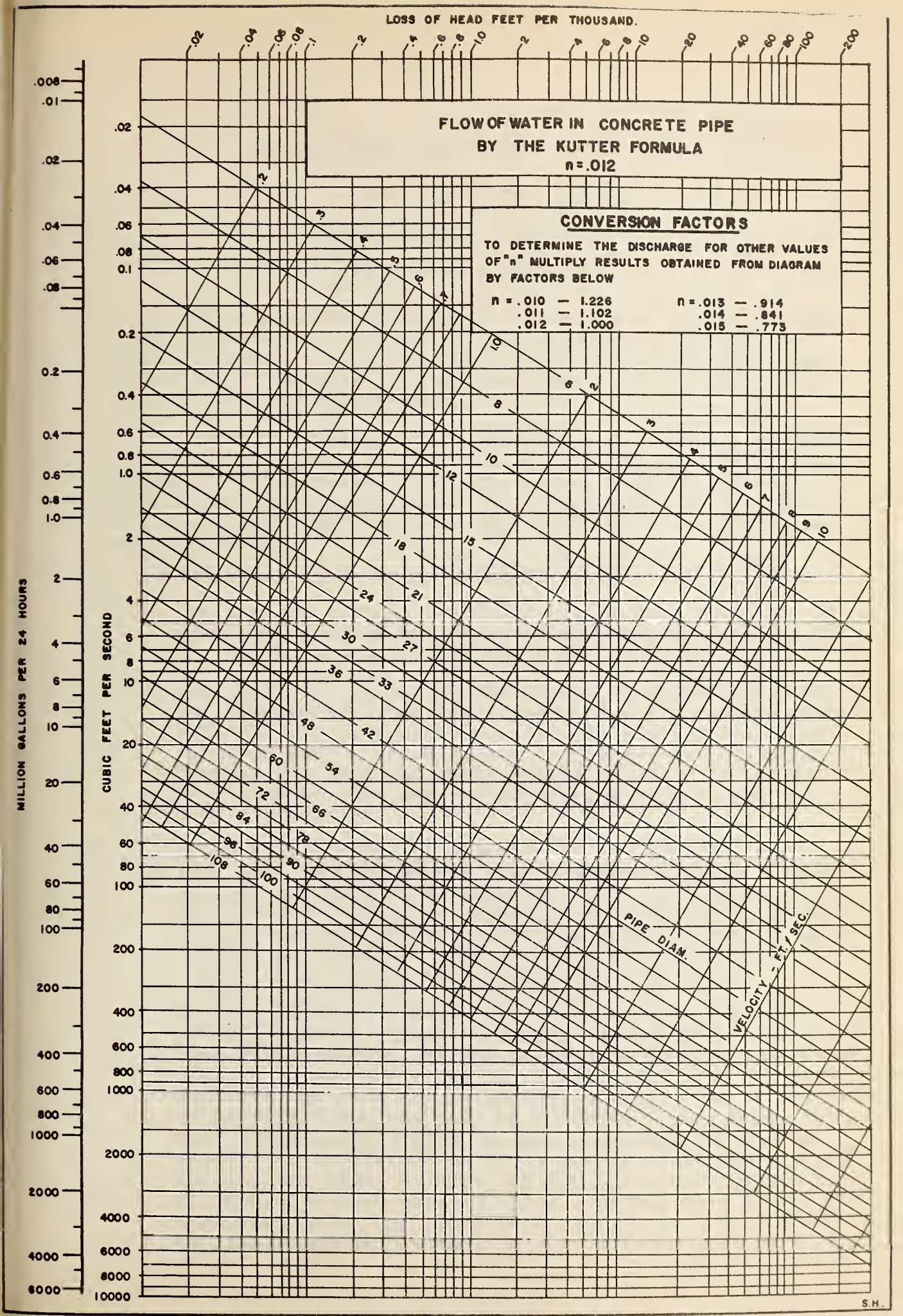
TYPICAL TRICKLING FILTER FLOWSHEETS.

FIGURE 3.

GRAPH SHOWING TYPICAL HOURLY RATES OF SEWAGE FLOW AT TREATMENT PLANT



GORE & STORRIE LIMITED
FEB 22ND 1956


LOSS OF HEAD FEET PER THOUSAND.
.02 .04 .06 .08 .1 .2 .4 .6 .8 1.0 2 4 6 8 10 20 40 60 80 100 200
FLOW OF WATER IN CONCRETE PIPE
BY THE KUTTER FORMULA
n = .012
CONVERSION FACTORS
TO DETERMINE THE DISCHARGE FOR OTHER VALUES OF "n" MULTIPLY RESULTS OBTAINED FROM DIAGRAM BY FACTORS BELOW
n = .010 — 1.226
.011 — 1.102
.012 — 1.000
n = .013 — .914
.014 — .841
.015 — .773
MILLION GALLONS PER 24 HOURS
CUBIC FEET PER SECOND
.008 .01 .02 .02 .04 .04 .06 .06 .08 .08 .1 .2 .2 .4 .4 .6 .6 .8 .8 1.0 1.0 2 2 4 4 6 6 8 8 10 10 20 20 40 40 60 60 80 80 100 100 200 200 400 400 600 600 800 800 1000 1000 2000 2000 4000 4000 6000 6000 8000 8000 10000
2 3 4 5 6 7 8 9 10
6 8 10 12 15 18 21 24 27 30 33 36 42 48 54 60 66 72 78 84 90 96 100 108
PIPE DIAM.
VELOCITY - FT. / SEC.
S.H.

SEWAGE WORKS OPERATORS' COURSE NO.1

February 20-24, 1956

SUBJECT: PLANT MAINTENANCE

Instructor: D.P. Scott

The objectives of sewage treatment are (1) to produce a good effluent; (2) in doing that, to cause no nuisance to the neighbours around the plant; and (3) to make the plant clean and attractive. To achieve each of these objectives requires proper maintenance.

I wish to warn you that Metropolitan Toronto intends to have the finest, best-kept plants on the continent, although we still have a long way to go. However, we will welcome all the competition you gentlemen can give us who are operating plants in the areas of Ontario outside Metropolitan Toronto.

There are three types of operators:

(1) The man who expects everything to be done for him. If something goes wrong, he wants somebody to come and fix it, supply a new part or buy a new machine.

(2) The "haywire" type, who "keeps her going" by patching the equipment. Year after year there are more and more patches, but he manages to keep the plant going. The operator may be proud of his handiwork, but the plant becomes run down and, when another operator comes in, he is amazed that anyone could let equipment get in such a condition.

The "haywire" type of operator is admirable, I grant you, to a certain extent, but the man I want is (3) one who has a vision of what he can make of his plant. He wants a plant that just sparkles from the road, through the grounds and buildings, to the final effluent. Of course, he should be able to use haywire when necessary, but he is not going to be satisfied with that.

At this point, I wish to mention the responsibility of the operator in regard to funds. Sometimes, I think the operator feels that he has nothing to do with the money; that it is not his concern. I admit the operator does not have the last say in regard to money, but he certainly has the first say and, if he doesn't give voice to this, he probably won't get what he needs to run his plant. It is obvious he won't get it if he doesn't ask for it, but then, he must ask for the money correctly. He shouldn't just say, "I think I should have $3,000 for improvements to the plant next year." He should study his plant and decide what he should do in each part of

it during the next year with regard to painting, building repairs, grounds, roads, equipment repairs and replacements, tools, etc. When he writes his report, he should give information as to the conditions that exist, stating why he needs money for each particular item and what will be accomplished. In some cases, this should be done in consultation with his superior, the engineer or superintendent.

The second responsibility is to make the best use of the allotment of funds that you are given and make sure that it is used to the best advantage of the plant and the community.

Thirdly, if you don't get all you ask for, you should improvise and carry on with your plans the best you can. In some cases, I feel that the plant operator is too close to his job, and he thinks, "The only way I can handle this is to get a new piece of equipment" and, when his request for that is turned down, he has to look at the problem differently. I remember a professor who used to say, "If you can't solve a problem one way, go at it in exactly the opposite way." I think this often proves to be a good approach to problems.

Where plants are only attended during the day time, it is absolutely necessary to have the plant completely fenced to keep children from damaging the plant and also to keep them from falling into the tanks or getting into the sludge drying beds. In one case, children threw some lengths of pipe into the final settling tank, which jammed the sludge collector and bent one of the shafts before the shear pin broke. Stones and other items thrown into the primary or final settling tank can block sludge lines.

In small plants, the expense of mechanical screens or comminutors is not justified. Bar screens should be cleaned properly and at sufficiently frequent intervals in order to prevent overflows and by-passing which would spoil the effluent from the plant. I might mention that, in replacing bar screens, it is a good idea to make sure that the new screen fits the teeth of a garden rake. The operator always ends up with a garden rake, regardless of what is originally specified. The screen should be designed so that the prongs of the rake project through to the underside of the bars. The spacers and supports should be arranged to let the rake slide over them, so that the rake can be pulled from the bottom right through to the top, without catching.

Grit removal equipment is placed in the plant for a purpose, and it is most important to keep it cleaned out and operating in proper manner, so that the grit will be removed and not allowed to collect in primary, aeration, final or digestion tanks.

In the primary tanks, skimming is important to get rid of grease and floating materials, which often cause odours and will spoil the effluent if allowed to continue through the plant. In pumping sludge, you must be sure that you are actually removing the sludge from the primary tanks. Very often, despite steep slopes on the sides of the hopper, the sludge becomes built up on the sides, with the liquid being drawn through a cone in the sludge. It sometimes stays there, becomes septic, and floats to the surface, or it can on occasion, after it has become fairly solid, slip down the sides of the hopper and block the withdrawal pipe. A reciprocating piston pump will generally remove the sludge better than a centrifugal pump, as the pulsating action tends to shake the sludge down the sides of the hopper. However, at one plant, even with a piston pump, the operator had to push the sludge down the hopper periodically with a pusher on a long pole.

A major problem in regard to the maintenance of aeration tanks is the control of suds. When the plant is not too heavily loaded, instead of keeping the activated sludge about 25% by 30-minute volumetric test, it should be kept up to about 40%, as this will assist in eliminating the suds. However, when the plant becomes loaded or overloaded, it is necessary to drop back to the lower percentage, otherwise considerable sludge may go over the final weir to the effluent when the sludge becomes under-aerated. If the suds are allowed to dry, it leaves a sticky deposit on concrete, pipes and handrails, which is difficult to remove. Therefore, it should be hosed and cleaned off before it has the opportunity to dry.

With regard to cleaning in general, I think it is most important that a sewage plant should be kept just as clean as it is possible to keep it. I expect the cleanest room in your house is the bathroom. Your wife probably cleans the bathroom once or twice a day, whereas she may clean the living room only once a week or less. The bathroom is kept clean because it is subject to the most dirt. For exactly the same reason, the sewage plant must be kept clean, because it is subject to so much dirt.

To keep it clean requires work and organization. I expect you are quite familiar with work, but I would like to comment on organization. The first thing which I consider important is the establishment of a routine of cleaning to cover the whole plant, to clean routine dirt so that, within a period of time, say a week, every part of the plant is cleaned. Then, when you have worked out the routine required, be sure and follow it. Secondly, make a practice to clean up what might be called "special dirt" right away. Frequently, when a sludge pump is dismantled or a check valve cleaned, the effort is placed only in getting the plant operating properly again, and spilt sludge or grease is left where it is

until it is spread around and makes a mess of a large part of the plant. In such cases, cleaning up should be considered an integral part of the emergency repair job.

In regard to grounds, it is important, when you come in to the plant each morning, to look at it from the point of view of an outsider. There may be papers on the lawn, which can easily be picked up. If left there, they would create a bad impression. Some equipment or material may have been left in a prominent place, which should be put away, or moved to a less prominent location. If we could every so often take the point of view of the outsider with regard to all phases of the plant - taking an objective point of view - we could see where we could improve the plant just from a general housekeeping point of view.

Then, of course, it is important to keep the grass neat and trim. Don't forget outside the fence, if there is a fence. We sometimes assume that anything outside the fence is not our responsibility. Most householders cut the grass and clean right out to the road curb. You don't want the appearance of your plant spoilt by a neglected boulevard.

Don't neglect maintenance of concrete structures, Sometimes, repair work on these would be a major job, and it would be necessary to call in a contractor. However, small repairs can often be made by the plant personnel. When you do the repairs yourself, be sure to clean off all loose and soft concrete leaving only the solid concrete. Use a bonding material to get a tight bond between the new and old concrete. Make sure that the cement you use is fresh and the sand or aggregate is clean.

Buildings must be kept clean on the outside as well as inside, properly painted, and the windows clean. A plant with dirty windows looks deserted and run-down. Keep eavestroughs in repair for the sake of the appearance of the building and to prevent the roof water spoiling the landscaping and the foundation plantings. Inside, the buildings should be orderly, You should have a place for each tool, and each should be in its proper place when not in use.

Don't forget the plant pipes and sewers. Although the sewer maintenance crew look after the sewers on the street, sometimes the man in the plant concentrates on sewage treatment and does not pay proper attention to the sewers through his plant. Inspecting and cleaning up sumps and pipe lines should be done from time to time. At one plant, we found some pipe lines were blocking up about every three months. We therefore established the practice of cleaning them every two months, to prevent the blocking. If you wait until something blocks up, then you have to clean it out when it does block, which will probably be at a most inopportune time and will interfere with the operation of the plant.

Mechanical equipment requires lubrication. Make sure you lubricate all the points that should be lubricated and that you use the proper grease or oil. As an example of what can happen; twenty-five years ago, at one of our plants, a clarifier driven by a large gear was left operating overnight without proper lubrication by the construction contractor. During that one night, at least two thirds of each tooth on the gear was worn away. With proper lubrication, the clarifier has operated continuously for the twenty-five years since without any apparent additional wear.

Watch for improper alignment. There shouldn't be vibration if a machine is properly lined up. If you cannot fix it, then you should obtain the services of a mechanic who can. Bearings should be checked once in a while and replaced, when necessary, in order to prevent damage to the shaft requiring a major repair job. Be observant and notice changes in the sound of equipment, which may indicate they need attention. Because you are in the plant every day, you are apt not to notice gradual changes.

Some operators tend to keep clear of electrical equipment and not without reason, but you should watch for electrical trouble and try to get it fixed before it gets you in trouble during a storm or at some other time when a breakdown is most inconvenient. That requires routine inspection of your switching, equipment, brushes, electrical contacts, etc. Some electrical repair work you may not be able to do yourself, and you may have to obtain the services of a qualified electrician. If that is necessary, plan all the work for which an electrician is needed beforehand, and have him do the whole thing at one time. Keep your electrical equipment clean of dust. Moisture in the air condensing on the dust will frequently cause a short circuit.

With regard to centrifugal pumps, you have to watch the packing glands to be sure that enough water, and not too much, is getting into the glands. Fairly often, check the capacity of your pump to see if it is losing capacity. Sometimes, you assume the pump is pumping the same as it always did, and this may mislead you when making calculations of plant flows. If a pump is not pumping up to its original capacity, it may be necessary to have the impeller built up, to restore it to its normal capacity.

The tubes, flues and air ducts of hot water or steam boilers should be cleaned regularly and, in addition, the passages for sludge in sludge beaters or heat exchangers. The burners should also be inspected and cleaned periodically. The flue gases should be checked occasionally, to see that the burner is working efficiently. Check the water level in the boiler to make sure it is within the required limits and that the water make-up valve is not blocked, either open or closed. If the water level goes down, the boiler may go dry and crack or, if water is continually being added, scale may

It is just as important to keep the records of maintenance as it is to keep the records of operation. The old saying "An ounce of prevention is worth a pound of cure", I think, is very applicable to maintenance of sewage treatment plants.

(Some slides were then shown to illustrate a few points with regard to maintenance.)

SEWAGE WORKS OPERATORS' COURSE NO.1

February 20-24, 1956

SUBJECT: PLUMBING AND CROSS CONNECTIONS

Instructor: A.E. Berry

Introduction

Plumbing is related closely to sewage works, and every sewage works operator should have a general knowledge of the legislation and how this is administered. This applies to the sewage purification plant as well as sewage pumping stations. This legislation is significant in that

(a) The Works Department or municipality usually installs the building sewer from the street sewer to the street line. This connects with the plumbing system on the premises. All plumbing on the premises must comply with Provincial Regulations which are in effect in all municipalities.

(b) Plumbing on premises,if not installed properly, may permit contamination of the water supply and may cause considerable inconvenience and annoyance to the property owner.

In both cases, a good knowledge of plumbing is essential for the sewage orks operator.

The Legislation in Ontario

The Province of Ontario has Plumbing Regulations or a Plumbing Code which is applicable to all urban centres. It specifies precisely how this work is to be done. This legislation came into effect on May 6, 1953. This makes the requirements uniform for all places in the Province. Formerly local by-laws varied a good deal from place to place and many of them were contradictory.

Some features of these Regulations call for review.

1. The Regulations and Local By-Laws.

The Provincial Plumbing Regulations supercede all local by-laws on all matters included in the Regulations. Thus, local by-laws no longer are applicable to any item covered in the Regulations. The Provincial Code is not a minium standard, it is the law applicable to all communities. In certain sections of the Regulations there are choices given on the use of materials or the way the work can be carried out. That choice rests with the owner of the premises rather than with the municipality in which the plumbing is being carried on.

2. Definitions

A number of definitions are listed in the first part of

the Regulations. The terminology used here should be noted, and it is well to be familiar with these terms and to use these rather than other names which may be in common use in certain places.

3. Who Does The Plumbing

The Regulations do not stipulate who shall be permitted to do plumbing but merely how it is to be done. Municipalities have the right to licence plumbers under authority given by the Municipal Act. That is optional with the municipality. Some have made use of this while others do not. In either case, the plumbing must be done according to the Provincial Regulations.

4. Kinds of Materials

The kinds of materials permitted in plumbing installations are listed in the Regulations. Specifications are also included for these along with information on where these materials may be used. In most instances there are choices given.

It will be apparent that new materials will come on the market from time to time. There is provision for revising the Regulations to include these when the Advisory Committee is satisfied with them. An example of this is plastic pipe for water service lines. This material is not included in the Code, but the Committee has agreed on its adoption when suitable specifications are included.

5. Cross Connections

All cross connections between potable and non-potable water supplies are prohibited under Regulation 23. Different methods may be used to prevent contamination of water by such connections or by other means. This is an important part of the plumbing regulations. It may occur in sewage works unless care is practiced.

6. Back-Siphonage

Back-siphonage is a major problem in plumbing installations. It may occur in places where it is not noticed or suspected. It is necessary for all operators to be alert for this at all times. It is more likely to be found in plumbing which has been altered subsequent to its original installation. The requirements in respect of back-siphonage are found in Regulations 41 to 44.

Some conditions which may be conducive to back-siphonage are:

(a) Water faucets which may be submerged before the fixture overflows the rim.

(b) Fixtures, tanks, sterilizers, etc., receiving water through the bottom.
(c) Faucets to which are attached hose lines which are at times submerged in water.
(d) The use of ejectors on laundry tubs for removing laundry water unless the ejector is equipped with a backflow preventer.
(e) A water line connected to a sewage pump for cooling or other purposes.
(f) A submerged inlet to a swimming pool or any submerged inlet to a commercial tank, cooler, condenser or other appliance.
(g) Drinking fountain where the orifice is below the overflow rim of the basin.
(h) A flush valve on a toilet where no backflow preventer is used.
(i) A hose line used to flush a choked sewer.

These are but some of the conditions which may give rise to back-siphonage. It may occur wherever there is a negative pressure at any point in the water line.

Prevention of backflow is specified in the Regulations. Most important are the means for preventing submergence of the inlet pipe. Flow preventers are permitted and can be used to advantage in a number of places where it is not possible to avoid back-siphonage by other means.

7. Sizes of Pipes

The minimum sizes of water pipes and waste pipes are given in various parts of the Regulations.

8. Used Pipe

No used pipe other than that which has been used for conveying potable water may be installed in a potable water system, and all pipe must be thoroughly cleansed before it is put into use. This applies to water pipes. In other cases, pipes and fixtures may be employed a second time provided they comply with the Regulations.

9. Water and Sewer in the Same Trench

It is permitted to install a water service pipe and a building sewer in the same trench but only if the water pipe is laid on a bench to one side. See Regulation 37.

10. Drinking Fountains

Specifications are given for the design of drinking fountains and for the waste lines which carry water away.

11. Inspection

Inspection of all plumbing installations is a local responsibility. The Inspector is sometimes employed by the Local Board of Health and sometimes by another Civic Department.

12. Responsibility of the M.O.H.

The enforcement of the Plumbing Regulations comes under the Medical Officer of Health and the Local Board of Health. It is their responsibility to see that the Regulations are observed. Inspectors are engaged for this purpose and they are accountable to the Medical Officer of Health and the Board of Health.

These Regulations refer to group systems.

Group A includes the water works part of the plumbing.

Group B includes the drainage parts and Group C systems are those installed in public access buildings. All these merit careful examination in respect to the possibility of their contaminating water supplies and causing annoyance to the property owners.

13. Traps and Venting

In general, all plumbing fixtures require traps to prevent the escape of gases from the pipes or from the street sewer into the building. Venting is also required in order to ensure that the water seal in the trap is now withdrawn. A number of different conditions apply, and it is important that the Inspector becomes familiar with these requirements. It will be noted that it is not a requirement of the Regulations to install a main building trap. It is cptional with the owner of the premises, but if he chooses to put it in, it must be installed as specified in the Regulations.

14. Testing of Plumbing Systems

The Regulations stipulate the tests which are to be applied to plumbing installations. These include a ball test on the drain, a water test on the piping and an air test to the piping in part or completely. The final test is known as the smoke test and is applied to the entire system.

15. Cleanouts

In the installation of a plumbing system in a building, it is necessary to ensure adequate facilities for cleaning different parts of the system where chokage may occur. In general, the system is so constructed that there will be little tendency for accumulations to form. The slopes and changes of direction are gradual rather than sharp. The details of the venting systems are outlined in the Regulations.

SEWAGE WORKS OPERATORS' COURSE

SUBJECT - HYDRAULICS

Instructor: J.G. Powell

It is the purpose of this discussion to describe, in a general manner, the application of hydraulics to sewer systems and to the treatment of sewage.

SEWER SYSTEMS - Separate or Combined

In modern municipal sewerage practice, sewage and drainage is collected, either in a single combined system or in two separate systems, one for sanitary flow and industrial wastes, the other for ground water and storm drainage. In former years, combined systems were most common because of economy and because the treatment of sewage was not given the consideration it is today. Today, the authorities are faced with an increasing demand for the abatement of pollution in our natural waters and, as a result, sewage treatment processes have been made more effective so that generally a high degree of sewage purification is provided. In order to maintain effective operation of the treatment process, the various plant units should not be overtaxed. Where separate sanitary sewer systems are used there is generally a saving in the cost of building the treatment plant because the volume of sanitary flow is relatively small compared to the volume of storm flow.

For instance, the maximum rate of sewage flow from one acre of a modern residential development is estimated to be approximately 7,500 gallons per day, while the rate of storm run-off from such an area, during a severe storm, might well be upwards of 540,000 gallons per day or about 72 times more.

It is never practical to provide sewage treatment for all the flow from a combined system. Usually only the dry weather flow is completely treated and up to two or three times the dry weather flow is given primary treatment. The balance of the flow during storms is by-passed directly to the receiving waters. Although the by-passing of surplus flows from a combined sewer system is not particularly hazardous because of the dilution usually afforded by the storm water, nevertheless, such by-passing is adding pollution to the receiving waters. From an operating standpoint, the combined system is not as free from complaint as the separate system of sanitary sewers in which, if properly designed and operated, by-passing is not necessary except in case of an emergency. Thus the trend is toward the construction of separate sewer systems, one for sanitary flow and the other for storm drainage.

SANITARY SEWERS -

Sanitary sewage comprises the soiled or waste water from a community, together with a limited amount of infiltration. It is generally found that the volume of sanitary flow is about equal to the water consumption. Water used for lawn watering, fighting fires, street flushing and used by railroads and certain industries does not reach the sanitary sewers but is just about balanced by the ground water infiltration or leakage into the sewers. It is found that the quantity of sanitary sewage flow from a municipality ranges from 60 to 150 gallons per capita per day, depending on the extent of metering individual water services and the water used by industry. The greater part of the sewage is discharged during the day time and sanitary sewers usually are built to handle two to three times the average rate of flow. It is common practice to design local sanitary sewers for a maximum flow of 300 gallons per person per day. Where development is to be light residential, a lower allowance may be used and where commercial and industrial establishments predominate, the figure should be higher.

The quantity of sanitary sewage depends on the contributing population. In an average municipality, population densities of 40 persons per acre may be found where housing is multiple family dwellings or apartment buildings. Our older residential areas were planned with lots of 25 to 30 feet frontage and when built up, have from 20 to 30 persons per acre. Planning for modern residential development is generally based on providing lot widths of from 40 to 75 feet and for built-up populations not over 15 persons per acre. The sewer designer must consider such factors and provide ample capacity for all types of development. For average conditions, a built up density of 25 persons per acre is commonly provided for and a sanitary sewage flow of about 7,500 gallons per acre. Common hydraulic formulae for computing sewer sizes give capacities in cubic feet per second. A sewage flow of 7,500 gallons per acre, per day, is the equivalent of a flow at the rate of 0.015 cubic feet per second.

The network of sanitary sewers serving a community is developed by a careful study of the topography of the area. Beginning at the boundaries, sewers are planned a block at a time, draining by gravity down through lower lying areas to the main collector or trunk sewer which, in turn, may be joined by other trunk sewers. The cumulative flow is discharged into the outfall sewer extending to the sewage treatment plant. The method used for computing the various flows is to measure in acres the area of each block or local drainage area from a plan drawn to scale and apply the basic rate estimated for the built-up conditions. Beginning at the boundary areas, the flows from each of the local areas are totalled cumulatively and the carrying capacity required for each length of sewer is thus ascertained. It is probable that

only part of the complete sewer system will be built initially and that sewers of lesser capacity than for the overall scheme will serve. Nevertheless it is usually economical to build the system to a plan for an expanding development that will take care of the forseeable future.

Where separate sanitary sewers are provided, the authorities should require that two private drain connections be carried into all premises, one for sanitary sewage and one for the run-off from eaves, paved courts, foundation drains, etc. Weeping tile drains around the foundations of buildings should be connected to the storm sewer and not the sanitary sewer. A local ordinance to exclude from the sanitary system all drainage other than sewage is necessary and should be strictly enforced, as otherwise the sanitary sewer will prove inadequate.

STORM SEWER SYSTEM -

Separate storm sewers and combined sewers provide the underground channels for carrying off rainfall and ground water drainage. The degree of protection from flooding during storms, the resulting property damage, nuisance and inconvenience that may occur are the first considerations to be decided upon in the building of a system of sewers handling rainfall. It is not economically feasible to construct sewers of sufficient size and capacity to take the run-off from the extreme storms that may occasionally occur. The overtaking of combined sewers, which are directly connected to basements, is definitely more objectionable than overta ing separate storm sewers. With combined sewers there is the hazard to health and property from domestic sewage, present in the combined flow, flooding into basements. Thus the quantity of storm water for which sewer capacity must be provided should be carefully considered. It may be somewhat less for separate storm sewers than for combined sewers.

The rate of rainfall is measured at various gauging stations throughout the province and from these gaugings, rainfall curves may be prepared which can be used as a basis for the economical design of storm sewers. Figure No. 1 illustrates the intensities of storms that have occurred in the Toronto area and the design curve adopted by Metropolitan Toronto.

In Southern Ontario it is common to build storm sewers to take care of rainfall intensities of from two to two and a half inches per hour for short periods of 15 to 20 minutes and for intensities of about 1 inch per hour for storms lasting an hour or more. As a rule combined storm sewers are built to take care of the heaviest storms that may occur in about a five year cycle. Where separate storm sewers are

used, some surface ponding can occur without causing damage or nuisance. Thus it is practical to reduce the capacity of separate storm sewers by from 25 to 50 per cent of the capacity necessary for combined sewers.

For computing the storm water quantities, the most widely used method known is the Rational Method. In this method the run-off is a function of the tributary area and the rainfall intensity, and is arrived at by estimating the imperviousness of the ground surface and the proportion of the total rainfall that reaches the sewer.

The method is represented by the formula

$$Q = CIA$$

in which Q = The quantity of storm water entering the sewer in cubic feet per second

C = A coefficient of imperviousness representing the ratio of run-off to rainfall and depending on ground slopes and the extent of impervious areas

I = A rainfall intensity in inches per hour equivalent to cubic feet of run-off per second for all practical purposes. A rainfall of an intensity of 1 inch per hour on 1 acre is equivalent to a run-off of 1.008 cubic feet per second

A = Tributary area in acres (43,560 sq. ft.)

The system of storm sewers is developed by a careful study of the topography of the area and by computing the various tributary flows in much the same manner as for sanitary sewers. The general route of natural drainage is followed in so far as practical, commencing in the outlying areas and following down to the point of discharge. Each local tributary area is measured, in acres, from a scaled plan and the flow is calculated based on the rainfall intensity decided upon and the coefficient of imperviousness for the type of development in the area.

Common values of the imperviousness coefficient "c" are:

Park Lands	- 0.20
Residential Areas	- 0.45 to 0.55
Commercial Development	- 0.60
Industrial Areas	- 0.60 to 0.75
Centre of Community Closely Built Up Business Districts	- 0.80

CAPACITIES OF SEWERS

Sewage is composed of about 99.9 per cent water and about 0.1 per cent pollutional matter, partly suspended and partly dissolved. Industrial wastes may increase the solids concentration somewhat and where storm water is included, grit and debris from street washings will enter the sewers in considerable quantities. In hydraulic computations, the sewage flow is treated as though it were clear water except that velocities must be kept sufficiently high to prevent deposits of solids.

Sewers are built to operate without surcharge and are normally only partly full. Thus sewers are actually open channels built of such size and at such grades as are necessary to carry away the flow by gravity.

Various hydraulic formulae have been developed for the flow in open channels. The Kutter formula is used most generally for computing the flow in sewers. In the use of this formula, the selection of proper values for the roughness coefficient "n" is most important. On the attached graph, Figure No. 2, is shown the capacities by Kutter's formula, using a roughness coefficient of .012 for sewers from 6 to 108 inches in diameter.

The roughness coefficients for common types of sewer pipes are as follows:

Well Laid Concrete Pipe, 24 inch diameter and over	- 0.012
Well Laid Concrete Pipe under 24 inch diameter	- 0.013
Well Laid Vitrified Tile Pipe	- 0.015
Cast Iron Pipe	- 0.015
Common Drainage Tile	- 0.017
Transite Pipe	- 0.012

The table shown on the graph sets out the allowance to be made when using value of the roughness coefficient "n" other than 0.012. The graph also shows the velocities in the sewers at various capacities. For sanitary sewers a minimum velocity of 2 feet per second is desirable and for storm sewers velocities over 3 feet per second are considered satisfactory.

Common minimum grades for sanitary sewers are as follows:

4-inch diameter - 1/4 inch per foot

6-inch diameter - 1/8 inch per foot

8-inch diameter - 0.40 feet per 100 feet

10-inch diameter - 0.30 feet per 100 feet

12-inch diameter - 0.25 feet per 100 feet

15-inch diameter - 0.20 feet per 100 feet

Some municipalities fix the minimum size for sanitary sewers at 10-inch diameter and for combined sewers at 12-inch diameter.

In concluding the discussion on sewer systems it is urged that operators see to it that sewer systems, particularly sanitary and combined systems are kept clean. Periodic inspection, at least twice a year, should be carried out and, where necessary, sewers should be flushed and rodded to ensure full capacity and to maintain them nuisance free. Manholes should be kept clean and where there is not proper benching and deposits occur, the benches should be built up in a satisfactory manner.

SEWAGE TREATMENT PLANTS

The quantity of sewage brought to the treatment works by the sanitary sewers or combined sewers, as they may be, varies considerably throughout the 24 hours of the day. Figure No. 3 illustrates the variations of flow on an hourly basis in a typical sewage treatment plant. Treatment plants are usually designed to serve a population that, based on figures of past growth, will provide for adequate treatment for an increase in population of upwards of 25 years in the future at the average rate of flow. Ordinarily an average flow of about 100 gallons per capita per day is provided for.

From a hydraulic standpoint there must be sufficient difference in levels between the invert of the inlet sewer and the maximum level of the receiving waters to allow the flow to pass through the various units of the treatment plant by gravity unless the flow is required to be pumped through the plant.

At the grit chambers the velocity of flow is reduced to allow the grit to settle out. Weirs of the proportional type are common at the outlet of grit chambers and provide additional depth of flow in proportion to the incoming rate so as to maintain a velocity through the grit chambers of approximately 1 foot per second which allows the heavier grit to settle out leaving the lighter organic solids in suspension.

In recent years the trend is to provide aerated grit chambers for larger plants, similar to aeration tanks of the activated sludge process. The flow is held in the aerated

chambers for a short period and the spiral rotation created by the introduction of a properly adjusted amount of air, keeps the lighter organic solids in suspension and allows the grit to settle out in a compartment at the bottom of the tank, where it is periodically removed by a clam shell bucket or by an ejector. Aerated grit tanks require very little hydraulic head to operate.

After the grit is removed from the sewage flow, velocities in the distribution channels extending to the primary settling tanks can be reduced to a minimum of about 1 foot per second. If lower velocities are desirable, the channels should be aerated.

Hydraulic losses must be provided for at the inlets and outlets of the primary and secondary treatment process. It is advisable to hold the level of the primary settling tanks at about the same level as the invert of the inlet sewer in order that the sewers draining to the plant will flush out during periods of low flow.

The inlets of settling tanks should be carefully baffled so that the flow will be distributed evenly throughout the tank. Overflow weirs are used for taking the effluent off the surface of the settling tanks. Where the settling tanks are of the longitudinal collector type, the weirs are usually troughs placed at about the three-quarter point in the length of the tank so as to avoid the rising current near the end of the tanks.

The solids settled out of the sewage flow are collected as sludge in the bottoms of the settling tanks. The sludge is withdrawn from the settling tanks by pumps. Piping for sludge is usually made oversize to allow for some build-up of grease deposits on the inside of the pipe and to facilitate cleaning of the pipe lines.

Cleanliness of all the tank units is very necessary and although the designer endeavours to provide for velocities in the channels between the units that will prevent the settling of solids, the operator should see that daily flushing of the channel and tank surfaces is carried out, in order to maintain the plant clean and free from odour nuisance.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: ODOUR CONTROL

Instructor: E. H. Baldock

The control of odours is without doubt one of the most important problems which has to be considered by any sewage plant operator. At one time or another, practically every sewage treatment plant is faced with an odour problem, regardless of how modern is the design, how efficient is the operation, or how attractive the plant looks. As soon as an odour problem arises it is essential that it be tackled right away, because all the good effects of previous good public relations with the citizens of a community can quickly be cancelled out if an odour problem at a sewage treatment plant is permitted to persist.

Some one once said that we should really not think in terms of "odour control" but rather in terms of "odour prevention". It is far cheaper and much more effective to remove the source of odours and so prevent the development of an odour than it is to try to control or remove odours which are already present.

All sewage, due to its high organic character, is a potential source of odour. It is also undoubtably a fact that many odour complaints pertaining to a sewage treatment plant are largely of psychological origin. At the same time, it must also be realized that it is quite possible for a sewage plant operator, who is constantly in contact with an odour, to have his sense of smell "paralysed" so that he does not realize that there is an objectionable odour present. Thus, when one receives a real or imagined complaint about an odour, it is essential that the complaint be investigated.

For the purpose of discussing odours I believe that the causes and possible remedies can be grouped under four headings: -

(1) Careless and untidy plant "housekeeping".

(2) Faulty plant operation.

(3) Incomplete plant design.

(4) Industrial Wastes.

(1) <u>Careless and Untidy Housekeeping</u>.

This is certainly one of the most unforgiveable causes of offensive odours at a sewage treatment plant, but is something which can easily develop if there is a lack of interest in his job on the part of the plant operator.

One of the most obvious sources of odour is the grit and screenings from raw sewage. A means of disposal must be found. If grit and screenings are allowed to accumulate in a pile in warm weather they will cause an odour due to the putrefaction and decomposition of the organic material present. Frequent disposal is essential in warm weather. The easiest solution to the disposal of grit and screenings is to select a site on the plant property in an inconspicuous corner where a neat trench can be dug. Then the screening and grit can be frequently taken to this pit and buried under a cover of about 6" of earth as soon as they are dumped. If this is not possible, it is desirable to have them trucked away for disposal as often as possible, and to store the material in covered containers until trucked away.

Any part of a plant where sewage solids are allowed to accumulate is another potential source of odour. This is where a high pressure hose can play its very important role as a sewage plant tool. Hose down open sewage channels, at your screens or racks, at your grit chambers, the exposed walls of your primary and final sedimentation tanks and aeration tanks. Special attention should also be paid to scum collection troughs if your plant has them. Be sure to check them regularly and keep them clean and free from grease which has a tendency to stick to the sides and if allowed to remain there will decompose to volatile acids which have a very foul odour. It is much better to have this material in your digester where the volatile acids produced are food for the bacteria which produce methane gas.

If your plant is bothered with foam in the aeration tanks, it is very necessary to hose down the walls and walks of your tanks as they will become coated with a heavy grease which again will decompose and produce an objectionable odour.

The interior of your plant buildings also requires your attention in order to eliminate sources of odours. It is advisable to keep your pumps, floors, piping and walls clean and free from accumulated debris. Spillages or leaks of sewage or sludge should be cleaned up as soon as possible.

If possible, try to have the interior and exterior of your buildings painted frequently. A painted surface is much easier to keep clean and it provides a much more pleasant atmosphere in which to work. If your place is tastefully painted it is psychologically easier to keep clean. It is also desirable to landscape the grounds with grass, shrubs, trees and flower beds. There is no reason why a sewage plant cannot be as neat and beautiful as a well cared for park. It is sometimes a definite advantage to have a row of tall trees around the perimeter of a plant as they tend to cause any odours which may be present at a plant to rise high into the air and be dispersed to the upper air.

It has been said that a plant which looks good, smells good, and a plant which looks bad, smells bad. A sewage plant is one place where people smell with their eyes. It is reasonable to expect a neighbouring resident who must gaze at a rundown and dirty plant everytime he sits on his porch, to imagine that he gets a foul odour from the plant. Figures on suspended solids and B.O.D. removal or bacterial counts mean absolutely nothing to a citizen who sees an untidy plant and who feels that the plant smells. It may take a little extra effort to keep a plant clean, but it pays big dividends in the development of good will.

(2) Faulty Operation

Faulty operation may be due to carelessness or lack of knowledge. Good operation of each process in a sewage treatment plant will usually result in an odour-free plant as well as producing a good final effluent, provided normal sewage flows free from heavy industrial wastes are received at your plant.

Good operation requires regular pumping of your primary sedimentation tanks, regulation of your return sludge to your aeration tanks, and regular withdrawal of digested sludge from your digesters. Failure to apply a regulated system of operation can result in the failure of any part of the sewage treatment process and this is always accompanied by objectionable odours.

If sludge remains for too long in primary or secondary tanks, it will go septic and cause a foul odour. This is especially the case in hot humid weather.

The aeration tank mixture should be watched. If the suspended solids become too high and the sludge volume index is too low it can result in settling in the aeration tanks at points where the tank turbulence is not great enough. An aeration tank should have a nice earthy odour which is the result of bacterial activity, but should not produce any foul odours.

Problems can also arise from faulty operation of a digestion tank. If a tank is overloaded with raw sludge it will result in low pH, high volatile acids plus "odour". If the supernatant liquor from the digester is returned to the primary tanks it will cause odours to appear here.

The withdrawal of too much digested sludge from the digester will deplete the tank of the seed which is necessary to promote good digestion of the raw sludge pumped into the tank. Again you will have poor digestion plu odour.

(3) Incomplete Design.

By incomplete design, I mean a plant in which no provision was made in the original design of the plant to take care of sources of potential odours as well as the plant which was well designed to handle a flow of say 2 M.G.D. but through bad planning is now called upon to treat 4 or 5 M.G.D. In either case you are likely to have an odour problem. The nice solution to cases of this kind is to enlarge the plant or alter the plant to take care of the deficiency. Usually the sewage plant operator who is confronted with this problem has to live with it for a long time as the desired solution involves considerable sums of money and the responsibility to provide it rests with the municipality and not directly with the plant operator. However, it is the job of the plant operator to get the best results possible from the plant as it exists. Especially with an overloaded plant, invaluable help can be provided by laboratory analyses. If laboratory personnel are not provided, then the plant operator should try to perform as many of the basic tests as he can so as to do the best job with what is available to him.

(4) Industrial Wastes

Industrial wastes receive the blame for most odour problems associated with sewage treatment, and in most instances they are the primary source of trouble. While domestic sewage also contains the essential ingredients which are necessary for the production of odours, it is usually only when heavy industrial loads are added to a sewage plant which previously has been free of odours, that it begins to have trouble.

Let us now look at how these objectionable odours are produced. The chief sources of odour in sewage are the decomposition products of fats and protein and compounds containing sulphur. Decomposition of fats by hydrolytic action causes fat to break down to fatty acids such as acrylic, butyric, valeric, caproic and caprylic. These are sometimes called goat acids and the name implies what odour one might expect. Decomposition of protein causes such compounds as indol, ($C_8 H_7 N$), skatol ($C_9 H_9 N$), mercaptan ($C_2 H_5 SH$) and hydrogen sulphide ($H_2 S$). Of all these the most important and most prevalent is hydrogen sulphide which is a colourless gas with a foul odour similar to rotten eggs. Hydrogen sulphide can result from the discharge of industrial wastes containing inorganic sulphides from such industries as tanneries and photographic processors or through biological actions of anaerobic decomposition of organic sulphates and the reduction of inorganic sulphates. Biological activity produces hydrogen sulphide from -

(1) compounds which contain organic sulphur formed from the hydrolysis of proteins, by the loss of the sulphydryl group;

(2) compounds formed from the degradation of soap, cellulose, starch and protein, are oxidized while the sulphate is reduced. ($CH_3 COOH + H_2 SO_4 = H_2 S + 2CO_2 + 2H_2 O$)

Some inorganic sulphate is present in community water supplies and organic sulphates are supplied by domestic waste, but the big source of inorganic and organic sulphates is from industrial wastes. Abattoirs, gut processing and wool scouring plants may contain 50-100 p.p.m. organic sulphur compounds. Since many industrial wastes contain such large quantities of the materials that are required for the production of hydrogen sulphide as well as other foul odours, it is usually their overload of these materials which cause an odour problem for a sewage treatment plant operator.

Much of the hydrogen sulphide odour which shows up in the raw sewage of a plant has been produced in the sewers - in the silt and sand layer in flat sewers and in the slime growth on sewer walls.

As well as having the required chemical compounds and proper types of anaerobic bacteria present for the production of hydrogen sulphide it is also necessary to have a favourable temperature for the bacteria to work. A temperature of above 70°F. is the most favourable. Thus the summertime is usually when most odour problems arise. Some of the hydrogen sulphide gas which is produced in a sewer and is carried to a sewage plant will likely be dissolved in the liquid. However, it will be released from solution due to turbulence such as a baffle, bar screens, or a weir, and it will not all be released at the first point of turbulence in a plant but may continue to be released at each point of turbulence. An illustration of how this phenomenon behaves is when a soft drink or soda water is first poured into a glass, gas bubbles are rapidly released but gradually the gas ceases to be released. However, if you stir the liquid additional gas is quickly released each time you stir it. A similar situation exists when hydrogen sulphide is dissolved in sewage and enters a sewage treatment plant.

Let us now consider some of the ways in which odours can be prevented: -

(1) As we mentioned at the first of the lecture, <u>cleanliness</u> is one of the easiest and most effective means of odour prevention.

(2) <u>Good plant operation</u> as we have previously discussed is another key to odour prevention.

(3) <u>Certain physical methods</u> can be applied.

(a) A reduction of turbulence can be effected by lowering weirs;

(b) Frequent cleaning of bar screens has the effect of increasing the flow velocity in sewers and can be the difference between a scouring velocity and one which allows sand and silt to settle in low-lying sewers;

(c) In dry periods and when the flow to a plant is considerably below normal the flow velocity in sewers can be increased by reducing the flow time through the plant, which is brought about by reducing from say two primary sedimentation tanks to a single unit;

(d) In some cases it has helped to add dilution water to the sewer system to increase the flow velocity. Of course this could only be tried in the case where the plant was designed to handle a much greater flow than it is presently handling;

(e) Pre-aeration of the raw sewage can be used as a means of removing hydrogen sulphide and other gases, and at the same time grease can also be removed. However, if pre-aeration is used provision must be made for the disposition of the gases removed. This can be accomplished in several ways -

(I) by a high stack -

(II) by a ventilator plus a high velocity fan -

(III) by burning - a temperature of about 1250°F is usually required to completely eliminate odours by burning.

(f) Have a good program of sewer cleaning to remove accumulated silt in the sewer system.

(4) By elimination of certain undesirable trade wastes.

A high or low pH (over 8 or below 6) is one clue that a trade waste is entering your sewerage system which can have harmful effects on your plant, either by producing odours themselves or by inhibiting the biological processes which are essential in sewage treatment processes. A low or high pH substance provides an unfavourable environment for bacterial growths used in sewage treatment and may also have a toxic effect on the bacteria. In any event, anything which tends to upset the biological activity of a plant will contribute to ineffective results and this usually results in odours, among other problems. Another clue to unusual amounts of trade wastes being dumped in a sewer system is greatly increasing B.O.D. values with small increases in suspended solids. There is a relationship between high B.O.D. values and the amount of H_2S which is likely to be produced at any given temperature and time interval.

To prevent the formation of odours, it is desirable to eliminate industrial wastes containing (a) sulphides, such as from abattoirs and packing houses. A reduction of protein organic solids slows down the production of hydrogen sulphide from sulphates, (d) toxic wastes, such as those from plating businesses and phenolic wastes from gas works etc. These wastes are quite effective in reducing H_2S production in sewers, but cause trouble in the sewage treatment plant processes.

(5) Use of Chemicals.

After all other means of eliminating odours have been tried we now come to the use of chemicals. At the same time as chemicals are used it is also desirable to continue to try to find what is causing the odour and eliminate it at the source.

The necessity of using chemicals will depend on the concentration. If it is less than 1.0 p.p.m. odour control is usually not necessary although a concentration as low as 0.001 p.p.m. has been known to carry for several miles over low, flat terrain on a still, hot, humid day.

Perhaps the most widely used and most effective chemical is chlorine. It prevents the formation of hydrogen sulphide by retarding bacterial decomposition and also combines with the gas, if any is present, in the sewage. ($Cl_2 + H_2S \rightarrow 2HCl + S$)

Chlorine can be used at several locations in a plant for odour control. In fact, many have found that it is most effective when applied at more than one point. Chlorination, called prechlorination prior to the primary sedimentation tanks will help eliminate odours in primary tanks and at the same time will aid in coagulation and thus help settling. The usual dose before primary sedimentation tanks is 60% of the chlorine demand. The dose necessary will vary from plant to plant, but it should not be so high as to produce a chlorine residual in the effluent from primary sedimentation tanks. Chlorine can also be applied in the pre-aeration chemical before aeration tanks if a H_2S is being produced here.

It may also be worth while to consider the use of chlorine at one or more points in the sewage system which feeds the sewage plant. This is often the cheapest way of producing an effective control. At one place it was found that 75 p.p.m. would be required to neutralize the hydrogen sulphide in the sewage at the sewage treatment plant, but that only 17 p.p.m. were necessary to free the sewerage system of the sulphate-splitting bacteria when applied some distance from the plant.

Some places use the Scott-D'Arcy Process which produces ferrous chloride from chlorine and scrap iron. This method has been found to be cheaper than using chlorine for just odour control purposes as the chlorine used also combines with the organic materials as well as the hydrogen sulphide, whereas, ferrous chloride re-acts mainly with just the sulphides and has little affinity for organic matter.

Activated carb n has been used with success at some plants for adsorption of odours. It is usually applied as a water slurry at a dosage of 3-5 p.p.m. to raw sewage.

At the Ward Island Sewage Plant in New York City, some success has been achieved with the use of ozone to combat foul odours.

A product called "choroben", an emulsion of mixed dichlorbenzenes, has been used with some success in some places and without success at others. It does not appear to be effective against sulphate reduction organisms and thus usually only combats part of the organisms which contribute to hydrogen sulphide production.

One chemical which has been used with considerable satisfaction here in Metropolitan Toronto is "polycide". By adding about one gallon per day of polycide to the raw sewage of an overloaded plant receiving about 2.5 to 3.0 M.G.D., we have been able to greatly relieve the odour problem.

There are other chemicals on the market which are intended to absorb or mask sewage plant odours and they all have had some successful applications. However, regardless of what chemical is used to remove odours it is wise to keep in mind that they usually do not get to the source of the odour, but rather mask the odour after it is present. It is cheaper and better to remove the cause of the odour before the odour develops.

Sludge drying beds and sludge lagoons are sometimes sources of odour, especially when one is using unheated digesters. It is desirable to get as much sludge digested in the summer as possible, and there is a tendency to put partially digested sludge out to the drying beds. Here again we have a potential odour problem and again chemicals such as chloride of lime, activated carbon, or a fine spray of polycide and water have proved themselves to be very effective in combatting the odours which rise.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: SEPTIC TANK

Instructor: K. H. Sharpe

General

The design of an individual or private sewage disposal system should take into account that location of wells or other sources of water supply, topography of the ground, water table, soil characteristics, area available, use and maximum occupancy of the building served.

All liquid wastes created in the dwelling either in the kitchen, bathroom or laundry can be disposed of in this system. Water from roofs, surface drainage, and footing drains should not pass into any part of the system.

The sewage disposal system should consist of a septic or settling tank with or without a siphon compartment, discharging into either a subsurface disposal field or one or more seepage pits. Where soil or other conditions are such that neither a disposal field nor seepage pit can be used, the approval of an alternative design should be obtained from the administrative authority.

Principles of Operation

The principles upon which the septic tank operates are simple. Some of the solid material carried in suspension in sewage is slightly heavier and some is lighter than water. If the sewage is allowed to remain quiet in a tank the heavier particles settle to the bottom and the lighter ones float on the surface of the liquid.

The material which settles is called "sludge" and that which floats "scum". The accumulations in the bottom soon begin to rot. The same action takes place in the scum to some extent but not so rapidly as in the sludge at the bottom. The decomposition process which changes part of the solids into liquids and gases is produced by the bacteria which are present in all sewage. It is not necessary to add yeast or any other material to start the rotting action in a septic tank.

The gaseous products of decomposition form very small bubbles within the body of the sludge and in time these bubbles increase the volume of the sludge enough to make it lighter than water; thus portions are detached and rise to the surface where the gases tend to escape. If all the minute bubbles should escape, the sludge would again settle, but free escape is interfered with by the material already floating and only part of the sludge returns to the bottom. The rest remains to increase the scum thickness.

The gases may pass out through the inlet sewer and escape into the air through the ventilating system of the house plumbing or into the ground through the field or through the joints in the tank cover.

The tank must be large enough to provide for storage of sludge and scum, and of such a shape as to allow the sewage which flows in at one end to pass very slowly and quietly to the other end where it is drawn off. The liquid waste which flows from the tank is called effluent. A certain amount of organic matter will not settle out. A properly designed tank should remove nearly all the settleable material, but the tank effluent is by no means pure, since very little of the organic matter in solution is removed by settling. Septic tank effluent, therefore, should not be discharged into any open ditch, stream, lake, storm-water drain or upon the surface of the ground. The liquid waste from the tank will putrify and cause an odour nuisance if allowed to accumulate on the ground surface, and it may contain pathogenic organisms. For those reasons, the effluent should be allowed to seep into the soil through some type of disposal field. Vegetables such as carrots, onions and radishes that are eaten raw should not be grown in the immediate vicinity of the disposal field.

The usual manner of providing a disposal field is to install lines of drain tile in specially prepared seepage trenches. The tiles are laid with open joints so that a portion of the tank effluent seeps out at each joint. The tile are surrounded with crushed stone to ensure a larger seepage area and the trenches are filled with earth so that they are neither conspicuous nor objectionable when located in lawns or other graded areas.

The effluent acted upon by soil bacteria is absorbed by grass and tree roots and other ways disposed of in a manner which leaves no nuisance or health hazard.

Septic Tank Location

1. Septic tanks should be so located that surface drainage therefrom is away from all sources of domestic water supply, and the elevation must be such to permit a minimum fall of 1/8 inch per foot in the building sewer.

2. The distance between a septic tank and any source of domestic water supply should be 50 feet, or more in the case of a porous subsoil or fissured rock, and the minimum distance between the tank and any building should be three feet.

3. The walls and floors of the septic tanks should be of water-tight construction. Metal tanks are recommended only for short periods of use and the metal should be at least 12 gauge in thickness and coated suitably to retard excessive corrosion. Any abrasion or defect in the coating of metal tanks should be recoated before the tank is installed or put into service.

4. The minimum capacity of septic tanks serving dwellings should be 400 Imperial Gallons in the sedimentation compartment. The inside liquid depth below the outlet should be not less than four feet.

5. (a) The length of the sedimentation compartment of a rectangular tank should be not less than approximately two or not more than three times the width. The direction of sewage flow should be parallel to the longest dimension of the tank.

(b) When circular tanks are used they should be laid horizontally and should comply with the requirements of subsection (a); or they may be placed vertically in series if each settling compartment has a minimum liquid capacity of 100 Imperial Gallons, and the combined capacities of all compartments be not less than 400 Imperial Gallons.

6. Inlets and outlets should be baffled or otherwise controlled to provide a quiescent flow and to prevent the escape of scum or floating solids. Baffle walls should extend the full width of the tank and be located 12 inches from the end walls. They should extend at least six inches above the flow line and not less than twelve inches, nor more than eighteen inches, below the flow line.

7. Submerged pipe inlets and outlets may be used instead of baffle walls. They should be tile or cast iron Ts or TYs with the long leg extending downward.

8. The invert of the inlet pipe should be at least three inches above the invert of the outlet.

9. Each compartment of a septic tank should be provided with a removable cover, or with one or more access manholes at least twenty inches in internal diameter. When manholes are used and only one is provided in the sedimentation compartment, it should be placed over the inlet end. Manholes should be extended to the ground surface or within six inches therefrom.

10. The liquid capacity of a septic tank for a dwelling should provide for a retention period of approximately twenty-four hours, with adequate additional space for sludge storage.

Estimates of Sewage Quantities:

The first step in the design of any subsurface sewage disposal system is to determine the quantity of sewage to be discharged and the size or capacities of the disposal units. Where there are water meters in existing buildings, the quantity of sewage can best be estimated from the meter readings.

Installation of Service Pipe:

Where measurements of water consumption are as, for example, when water meters are not available or where disposal facilities are being planned for a new building, it is necessary to use other methods of estimating the amount of sewage to be discharged. One way is to base the computed flow on the number of bedrooms or the number of plumbing fixtures. If the building is used as a restaurant, the number of patrons or the number of meals served may be the best criterion.

Table I
Septic Tank Sizes for Dwellings

Based on a sewage flow of 35 gal/cap/day, with the sludge storage of 6 cu.ft. per capita.

Number of Bedrooms	Maximum Number of Persons served	Width (inside) Ft.	Ins.	Length (inside) Ft.	Ins.	Liquid Depth Ft.	Ins.	Total Depth (Minimum) Ft.	Ins.
2 or less	4	3	0	5	6	4	0	5	0
3	6	3	0	6	0	4	0	5	0
4	8	3	6	7	0	4	0	5	0
5	10	3	6	7	6	4	6	5	6
6	12	4	0	8	0	4	6	5	6
7	14	4	0	9	0	4	6	5	6
8	16	4	0	10	0	4	6	6	0

The design for other than minimum capacities should be based on a minimum sewage flow of the following:

Dwellings and Boarding Schools - 35 gal. per capita + 6 cu.ft. sludge storage per capita

Small Hospitals (up to 15 beds)- 100 gal.per bed + 8 cu.ft. sludge storage per capita

Day Schools - 15 gal.per pupil

Tourist Camps, Motels - 20 ga. per capita + 3 cu.ft. sludge storage per capita or 100 gal.per unit per day.

Siphons:

The purpose of the siphon is to distribute the tank effluent at specific intervals throughout the length of the tile system. By discharging the effluent periodically, allowing time for aeration and seepage, bacterial activity in the soil is maintained.

Siphons are recommended for the best distribution of septic tank effluent, and also where sub-zero temperatures are common.

The liquid capacity of the dosing chamber should be sufficient to fill all pipes of the distribution system between 1/2 and 3/4 full at each discharge.

Sub-Surface Disposal Fields:

In planning for the septic tank, the location of the tile field should be given primary consideration. The depth of the excavation depends very largely on the elevation at which the tile field is placed. The ideal location is a level plot of ground of a sandy or gravelly nature about 2 feet lower than the ground surface at the tank.

The disposal tile system consists of four inch drain tile laid in trenches three feet or more apart, and not more than 2 feet below the surface. There should not be more than 12 to 20 inches of earth covering the tiles in order that grass roots and other minute plants and soil organisms may be used to the utmost in taking up the organic material in the sewage for plant food. Very little rotting takes place at a depth of more than 2 feet. The disposal tile should be laid with a slope, preferably not more than 1 inch of fall per 25 feet. The reason for laying the tile lines virtually level is to ensure a more uniform distribution of the sewage. If the tile line has considerable fall, the sewage will collect at the lower end, creating a saturated area which destroys the bacterial action in the soil and prevents the final rotting of the sewage.

The filed tile used should be laid with joints 1/4 to 1/2 inch wide, and the top half of the joint should be covered with asphalt treated paper or gravel or other suitable material to prevent the entrance of the soil.

With the exception of very porous sub-soil, all drainage pipe should be laid in a trench on a bed of gravel or crushed rock. In such cases there should be not less than 6 inches of gravel or crushed rock beneath the drainage pipe.

The trench width at the bottom should be not less than 18 inches. The effective absorption area is dependent on the bottom width of the trench, but no installation should have less than a total of 150 lineal feet of drainage pipe.

If there is a question relative to the ability of the soil to absorb the effluent, a measure of the absorptive ability of the soil can be obtained by making a simple percolation test. Dig a hole about one foot square to the depth of the proposed disposal trenches. Fill the hole with water to a depth of at least six inches and allow the water to seep away. Repeat this procedure until the drop in water level is at a constant rate. When a constant rate

has been reached, observe the time in minutes required for the water level to drop one inch. The effective absorption area may be then determined by the following table:

Trench Requirements From Percolation Test

Time (T) Required for Water Level to Fall 1 inch (Minutes)	Loading (G) per sq.ft. of Trench (Imp.Gallons)	Loading (G)per Lineal Foot for 18 in. Trench (Imp.Gallons)	Length of 18 in. Trench Required per person for 35 gals.per day flow
1	3.5	5.2	6.7
5	2.1	3.1	11.3
10	1.5	2.2	15.5
20	0.9	1.3	27.0
30	0.7	1.0	35.0
40	0.6	0.8	44.0
50	0.5	0.7	47.0
60	0.4	0.6	58.0

Note - Based on $G = \frac{29}{(T + 6.24)\ 1.2}$

In which G = the rate of sewage application in gallons per day per. sq.ft. of bottom Trench area and T is the percolation time in minutes per inch as determined above.

RECORDS AND REPORTS - F.Horgan

The title of my discussion today doesn't sound very inspiring, but I hope I can make it interesting for you, because it certainly is a very important subject. Some of the material I shall present may overlap a bit on some of the prior lectures, or on those to follow. However, repetition may only serve to get the point across.

What are records? Why do we keep them? How do we keep them? Where will we keep them? And reports? When are they necessary - How should they be prepared? That's quite a series of questions, and their answers merit serious consideration.

Records, for the individual, start the day you are born. In almost everything you do, your date of birth crops up; school, family allowance, employment, insurance, even your income tax, are all affected by that simple statistic. Perhaps that's why it is termed a "vital statistic". How important it is, therefore, that that date be recorded.

Speaking of statistics, the Federal Government maintains a Bureau of Statistics to compile and assemble records on all factors in Canadian business and economic life - including census, production, imports, exports, employment, etc. Police departments maintain records of crimes, criminals, etc. That's one location where it's desirable not to have a record, for an individual, yet for the protection and safety of the public at large, those crime detection and prevention records are extremely important.

In sports, the fastest miler, the leading goal scorer, the leading hitter, the top golfer, all provide records of a still different type. And in the field of music, sound, we have records, the kind that set our teen-agers agog. Parliamentarians have their every deathless phrase made just that by having them recorded in Hansard, the official record of proceedings of our governing body.

The Funk and Wagnall definition of the work "record" begins: "A writing, printing, entry or tracing made for the purpose of preserving memory or authentic evidence of facts or events". That pretty well answers the second question we posed at the outset - Why do we keep them? Simply because the thing recorded is of interest at the time it was noted, and it is expected to be of interest again at some time in the future. A written record of events is obviously more valuable than a mental note made by an individual, for our memories can play strange tricks on us. To clarify this point, let me ask you what do you mean by the term "an experienced man"? He is simply a man who has performed his job for so many days, months, or years that he has become familiar to a greater or lesser extent with the solutions to problems thay may be expected to confront him. That is why, when we are considering a man for a job, or for a promotion, we inquire about his experience. The experienced

man, then, is one who has a mental record enabling him to perform his work more efficiently than an inexperienced man. We "break in" the inexperienced man by working him alongside a man with experience, if at all possible, in order that he may benefit from the tips and the direction of the old hand.

Some jobs are of such little relative importance that it may not matter that there is no written guide to steer an untried hand in the right direction. But others, and the construction, operation and maintenance of a sewer system or a sewage treatment plant are certainly in this category, are so important that we cannot depend solely on the mental agility of the men we appoint to do the job. That is why you men are here - to gain some knowledge from the experience of those who are practised or trained in the science of sewage treatment and in the design of sewers to convey sewage to the point of treatment, or to drain off surface waters resulting from rainstorms. How important it is, then, that these men who have learned from experience should make a written record, as comprehensive as possible, for your benefit and for those associated with you and with them.

We probably all know of situations where the source of all information regarding the sewers in our community, or of the drains connecting to them, is "Old Harry So-and-So, He'll know - if he doesn't, nobody does". But all that points up is the fact that "Old Harry" or his superiors were delinquent in not requiring the maintenance of adequate records. Today, when the accumulated value of sewers and plants in communities of any moderate size is approaching the millions of dollars, we have a tremendous capital investment to safeguard, and adequate maintenance is fully dependent on the extent and accuracy of our record system.

I think that should answer the "why"? Next, we have the "how?" How are we to develop and maintain an adequate set of records?

I can't attempt here in the space of a few minutes to outline a system which will be foolproof for each of you. That is dependent on the size and complexity of your sewer system or sewage treatment plant. However, a few generalities may serve as a guide, either to enable you to start from scratch, or to evaluate the system you are presently using.

Let's start with the sewer system. Your designer lays out a plan, preferably showing both plan and profile views of the sewer to be installed. The plan is used by contractors as a basis for submission of tenders, and, before long, construction is under way. Your record system has probably been at work through this whole operation. The plan has had to be approved by your Council, the spending of the funds authorized by them, the approval of the department of Health of Ontario obtained for the design, and the approval of the Ontario Municipal Board to the spending of the funds, if they are to be raised by debenture issue, was also needed. The

sewer is being laid according to plan - but quite often underground conditions, such as the discovery of wet running sand, rock, or other unplotted utility lines, will necessitate a revision of the plan to overcome them. The recording of all revisions is very important, and should be shown on the plant- that is, an "as constructed" drawing should always be available in your files.

The development of individual sewers, when compounded time after time, leads to the development of your sewer system. As that system develops, it must be operated and maintained so as to give satisfactory service to the public. To do so, a suitable set of records is essential. A basic requirement of your maintenance yard is a map of the system, showing direction of flow of sewers and pipe sizes. Large-scale sectional maps should also be provided, showing exact locations of manholes, exact lengths of sewers, their grades, and directions of flow. Useful also is information on size, depth and construction material, date of construction, and locations of lateral connection somewhere in your organization, if not at the maintenance yard itself, then in your engineering office, should be available the detailed "as constructed" drawings, for reference in case of serious trouble occurring, and to indicate the location of other underground utilities with relation to the sewer. A small card index system, showing sewers on streets block by block, with locations and sizes of connections to the sewer referenced to the nearest downstream manhole, can be of great value. But such records are of value only as long as they are kept up-to-date. Construction of new manholes, new drains, etc. should be noted, and a suitable system worked out for making the required changes in the records, be they plans, maps, or cards.

Sewer inspection should become part of basic maintenance procedure, with a cleaning or flushing program and adjunct of the regular inspection. Repairs which may be found necessary as a result of routine inspection should be promptly made. Better to attend to minor repairs than to wait for a sewer collapse and be faced with an emergency condition. Modern cleaning equipment is available for sewer maintenance - although very often the Council, which controls the purse strings, is unsympathetic towards the need for expenditures for this type of equipment. However, a minimum of equipment, if sensibly used, can be made to serve quite usefully. Map out an area cleaning program, centralize your efforts in that area, and move gradually through your whole system; if possible, at least once every five years with your cleaning equipment, at least once a year with your inspection, and inspect trouble spots such as inverted syphons, overflow or drop manholes, gratings, etc., as often as once a month or as often as your experience dictates. Here again, records are important - dates on which work was carried out should be noted, and possibly the simplest way, a copy of your sewer map, shaded or coloured year by year to show areas inspected,

flushed, cleaned, etc., etc., should be maintained. If you have responsibility for cleaning and maintenance of catch basins as well, regular cleaning and inspection are musts. The sump in the catch basin is designed to prevent heavy grit, sweepings, etc. from the street reaching the sewer; if the sump is not kept clean, either the grit escapes to the sewer, or the catch basin blocks and floods the street.

Complaints received from the public, be they drain blockages, odours, floodings of one kind or another, should be promptly investigated, and a report of action taken, if any, should be placed on file.

That's our first mention of the word "report". However, reports are an important phase of both sewer and treatment plant work. Unless reports filed on action or findings in complaint investigations are accurate and comprehensive, they are worth little or nothing. Similarly, reports from your sewer inspectors should be comprehensive. The sample form of report, used by Metropolitan Toronto, ensures that, if properly completed, all pertinent data obtained during the inspection will be recorded. If no action is required, the report can be filed. If faulty conditions are found, the action taken can be noted by the maintenance engineer or superintendent. It may be that very bad conditions were found - if you haven't been inspecting regularly - and the corrective action is beyond the funds provided in your maintenance budget. That is where reports are of tremendous importance, to a municipal or governmental employee or to a private company. They must be concise, describe the problem, its remedy, and probable cost, thoroughly enough that a majority of your Council will appreciate your difficulty and vote the funds to do the work. If the report does not satisfy, no funds - makeshift repairs, relatively minor problems become major ones - and your maintenance program could break down to a panicky emergency-type operation, hard on you, your men, your budget, your tax-payers, and your sewer system. Reports can be the most onerous duty you have to perform, but a man who can make a good thorough written report is a prize indeed, and is always well regarded by his superiors. It is only by doing that you improve - the old saw: "Practice makes perfect" certainly applies.

You may be expected upon your return to home base to make a report on what you learned here - don't be afraid to tackle a written report. Jot down the outline of what you want to say - just a few notes on succeeding lectures, then elaborate on that framework, and finally, go over it and polish it up here, chop it up there, and you have achieved something of which you can be proud; and which will convince your superiors, whoever they may be, that this course is worth presenting to others on your staff in the future.

We've digressed a bit from records, so perhaps we'd better return to that theme. Before leaving the sewer system to discuss plant records, let's not overlook the fact that there may be a number of sewage pumping stations incorporated in our sewer system. It's a lucky man who has none of them to worry about, for they require constant attention. Constant attention also means attention to records of operation and pump and motor maintenance.

An electric power meter is usually provided, which gives relative information on the flow load. Excessive power consumption may indicate a clogged pump or open check valves. If a flow recorder is provided, the kilowatt-hours per million gallons of sewage pumped should be recorded. The latter figure provides a quick check on pumping efficiency.

Every operator should record daily which pumps are running and, if possible, the hours of daily use. Head recorders on the discharge piping are installed at some stations giving the static head and pumping heads. This information, when recorded on a daily chart, gives not only the pumping heads, but also the hours of pump service. Such recorders provide a valuable record of station performance, and an operator should see that the recorders are maintained, the charts changed daily, and the tracing pens inked. Lacking head recorders, the hours of use per pump may be obtained by installing time clocks or by using an ordinary electric clock plugged into the same electrical circuit on which the pump operates.

Free reference material:

C.G.E., Industrial Sales Section,
1 River Rd., Schenectady 5, N.Y.

1) "Productive Maintenance of Motors, Generators and Control", Booklet GED-1691. A pocket manual.

2) "How to Maintain Motors and Generators", Booklet GET-1202.

3) "How to Maintain Industrial Control", Booklet GET-1195B.

The operator should secure working drawings of the pumps and controls at his pumping stations from the manufacturer., including maintenance instructions.

Sewage Treatment Plants

Operating records provide for the systematic compilation and interpretation of plant data. Only by the use of records can the best operating results be obtained.

Every operator should have on file the designing engineer's preliminary report. This report contains the design data for the plant. A complete set of plans for the plant and sewers, together with the specifications for the

materials used, should be on file. It is very helpful to have a file of the manufacturers' detailed drawings and operating instructions for all the equipment installed. This information is priceless when repairs are necessary.

A schematic flow diagram of the treatment works, showing all essential piping, is useful for checking operations and for explaining the performance of the plant to visitors. The operator should prepare such a diagram or have the designing engineer do so.

From an article on "Qualifications for Sewage Works Operators", I quote:

"The ability to read and write the English Language is an obvious requirement for all operators except laborers. Reading ability is necessary to follow written instructions and to extend your knowledge. Plant record-keeping and reports require writing ability. Both reading and writing ability may be improved with practice.

"This matter of reading is important. By reading current and past literature in this field, much knowledge of value may be absorbed. Read, think, and act on the knowledge you gain. The operator who reads gains more from attendance at conferences and from personal contacts with experienced operators and others.

Recommended reading:

"The Technique of Clear Writing"
by Robert Gunning.
Published by McGraw-Hill Book Co. Ltd.

Your plant designer should provide or suggest report forms for the proper recording of necessary operating data. While record requirements vary over a wide range, depending on plant type and capacity and individual inclinations, it is desirable to provide at least two forms, one for daily entries and the other for a monthly summary. The daily form normally should include spaces for such items as power meter readings, sewage flow, raw sludge pumping, digester gas production, sludge removed from digester, and results of control tests. Space should be provided also for recording various temperature readings, for describing special operations, and for listing other items of particular interest.

The monthly summary is simply a form to record by months the totals of the various operating figures entered on the daily report form. Space should be provided for totals and averages, for total hours of operation of major pieces of equipment, and for notes and comments on the recorded data.

He should also design and set up a card system for maintenance duties, using either standard index or edge-punched cards. A card record system simplifies the job of organizing

and scheduling routine maintenance activities and, if properly kept, provides a valuable history of all work done in the inspection, testing, cleaning, lubrication and painting of equipment.

In the operation of sewage treatment plants, the following quantity measurements of sewage and sludge flow are commonly needed:

1. Raw Sewage
2. Recirculated discharge to high rate trickling filters.
3. Return Activated Sludge
4. Wasted activated sludge
5. Primary Effluent to secondary treatment units.
6. Raw primary and chemically-precipitated raw sludge.
7. Humus sludge
8. Digested sludge

These measurements enable the operator:

1. To determine from raw sewage flows the volume of wastes being handled at the plant, together with the detention, surface area loadings, and weir overflow rate of settling tanks.

2. To determine from recirculated flows or return activated sludge flows the added flow to high-rate trickling filters and activated sludge aeration tanks.

3. To determine from primary effluent flows the loading on all types of secondary treatment units, including standard or high-rate trickling filters, sand filters, and activated sludge aeration tanks.

4. To determine from raw, humus and digested sludge quantities the removal of sludge solids from the treatment units involved.

5. To determine from all of these measurements the cost of operation per unit volume of sewage or sludge, and to provide a permanent record of quantities which will point out plant loadings and overloads, when and if they occur.

Most of this information about the flow passing through various units of the plant is obtained from meters, which may act as recorders, registers or indicators. A recorder is a device that makes a graph of pressure, velocity, rate of flow, etc. of sewage, gas, sludge, water, etc. Recorders should be distinguished from indicators. Indicators are devices that show by a pointer or dial the instantaneous value of quantities; registers are devices that count quantities and may also include a graph of variations in magnitude of quantities and an instantaneous indicating device.

Thus, registers may totalize quantities and also serve the function of recorders and indicators. In the paper on "Instrumentation", you probably obtained an explanation of how these devices operate.

In the weekly operating report of our North Toronto Sewage Treatment Plant, you see the result of efficient record-keeping. As you can gather from reviewing these records, there is a tremendous amount of information to be absorbed and analyzed. As you look through the figures, bear in mind that this plant is currently overloaded; with a designed capacity of 7.5 million gallons per day, flow for the week of December 17th averaged 9.059 million gallons per day, or 20% over design loading.

The field of sewage treatment is a fast-growing one. Preservation of our precious water supplies, protection of fish and other wild life, of our beaches and recreation facilities, maintenance of property values on our rivers, lakes and streams, prevention of odours and of accumulation of sludge and consequent interference with navigation, water supply for farm animals, and the general attractiveness of an area - all emphasize the need for sewage treatment. More and more cities are turning to it, either through force or necessity, so that sewage treatment is a prominent field for the future, in which a man will do well to establish himself and grow.

The records of our existing plants, and the records of the many and varied experimental processes being studied in all its phases, are playing a major role. By the study of records, we are able to operate and control our existing facilities - we are also able to provide information for research into development of improved methods, reduced costs, both in original capital investment and in operation, better working conditions for our men, and the advancement of the sewage treatment plant from an odorous installation hidden in a remote corner of town to a well-landscaped addition to the municipal facilities, and a pride to its operators and the citizens of the community.

I hope you'll keep all that in mind the next time you fret about the need for keeping your records up-to-date, and for furnishing reports of your operation to your superiors.

SEWAGE WORKS OPERATORS' COURSE No. 1

Lecture delivered Wednesday, February 22, 1956
Lecturer: W.M. Walkinshaw, James F. MacLaren Associates, Toronto.

Mathematics:

The purpose of this lecture is to discuss some of the measurements and calculations which are useful to sewage treatment plant operators.

Measurements:

All calculations start with measurements. The accuracy of any calculation of an area, volume, weight, rate of flow, concentration, or other quantity can be no better than the least accurate of the measurements involved.

Significant figures in Calculated Results:

The instruments used in making a measurement may be capable of widely varying degrees of accuracy. It is important to remember that if the needed result must be stated to three or four significant figures the measurements must be made to the same degree of accuracy.

An example of the effect of an inaccurate measurement on a calculation is as follows:

> Suppose the three figures 24.72, 359.74 and 0.0016 are measurements and the product of the three numbers is needed.
>
> By direct multiplication the product is 19.98267648. Note however, that the number 0.0016 has only two significant figures thus limiting the accuracy of the result to two figures. Without loss of accuracy the other numbers can be rounded off to three significant figures. Thus we now multiply -
>
> 34.7 x 360 (each rounded off to 3 figures) x 0.0016
> 34.7 x 360 = 12,492 rounded off to 12,500
> 12,500 x 0.0016 = 20.0000 rounded off to 20.
>
> It is meaningless to round off the product to 19.98 or to 19.983 because of the possible inaccuracy of the measurement 0.0016.

Units:

It is safest to express all the measurements in the same system of units before using them in a calculation.

The system of units in common use in Canada is the English Gravitational System in which:

The unit of Length is the Foot
The unit of Force is the Pound
The unit of Time is the Second

Sometimes in scientific work other systems of units are used, usually one of the metric systems.

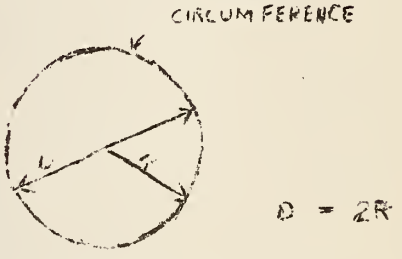
Using the English Gravitational System all lengths should be expressed in feet, areas in square feet, volumes in cubic feet, velocities in feet per second and acceleration in feet per second per second.

Work is expressed in foot pounds, power or rate of work in foot pounds per second.

Only after the basic calculations have produced the desired result in square feet, cubic feet per second, or foot pounds per second should the answer be converted into acres, or gallons per minute, or horsepower, or kilowatts.

Calculation of Areas, Volumes

Area of Circle:

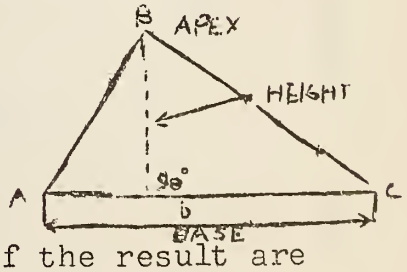


Area Formula - Area = $\frac{\pi D^2}{4} = \pi R^2$ Square Feet.

Circumference = π D - 2πR Feet

D = Diameter in Feet π = 3.1416
= $\frac{22}{7}$ nearly

R = Radius



Note that if a length occurs twice the units of the result are square feet and if length occurs only once the units are feet.

Area of a Triangle:

Area = $\frac{1}{2}$ bh, sq. feet

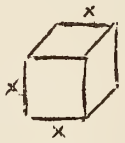
B = base in feet H = height or altitude in feet.

The altitude is the perpendicular distance from the apex to the base. Any angle, A, B or C may be taken as the apex and then the side opposite to that angle is the base.

Areas of four sided figures may be calculated by dividing them into two triangles.

Volume of a Cube:

A cube is a solid body having six equal, square sides.



If X is length of side in feet

Volume = x.x.x = x^3 cubic feet

E. G. if x = 3 feet - volume = 3^3 = 27 ft. or 1 cu. yard.

Volume of a Cylinder:

Circular cross section has radius R feet

Length of cylinder = H feet

Volume = area of the end x length

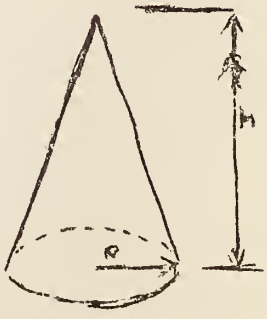
= πR^2 x H = $\pi R^2 H$ cubic feet

Volume of a Sphere:

Radius = R feet

Formula - Vol. = $\frac{4}{3} \pi R^3$ cubic feet,

Volume of Pyramid or Cone:



Radius of circular base = R feet

Altitude = perpendicular height from apex to the plane of the base = H feet

Volume = 1/3 x area of base x altitude

= 1/3 πR H cubic feet.

Measurement of Rate of Flow:

Often the rate of flow can be measured most readily by allowing the water level to drop in a tank of known dimensions. The time required to refill the tank through a given number of feet of rise will give the flow in cubic feet per minute which can then be converted to gallons per minute.

Some Useful Conversion Units:

1 mile = 5,280 feet = 1,760 yards

1 acre = 43,560 square feet

1 cubic yard = 27 cubic feet

1 ton = 2,000 pounds.

Unit of work = 1 foot pound.

Unit of power = 1 foot pound per second.

1 horsepower = 550 ft. lb. per sec.

= 33,000 ft. lb. per minute.

= 746 watts

= 0.746 kilowatts or nearly 3/4 Kw.

1 Kw. = 1.34 hp.

1 H. P. hour (work) = 0.746 Kw. hr. etc.

1 grain = 1/7000 pound.

1 liter = 1,000 milliliters.

= volume of 1 kilogram of pure water

= volume of 2.205 pounds of pure water.

Since 1 Imperial Gallon weighs 10 lb.
The liter = 0.2205 gallons between 1/5 and 1/4 gallon.

1 Kilogram (1 Kg) = 1,000 grams (1,000 g.)

1 Gram = 1,000 milligrams (1,000 mg.)

Therefore 1 Kg. = 1,000,000 mg.
= 10^6 mg.

1 mg. in 1 litre (written 1 mg./L) = 1 part by weight in 1 million parts by weight

Therefore 1 mg/L = 1 p. p. m. (parts per million)

1 grain per gallon = 14.3 p. p. m.

1 p. p. m. = 10 lb. in 1 million gallons

FLOW CONVERSIONS

C. F. S.	G. P. M. Imp.	M. G. D. Imp.
1.0	374.4	0.539
2.67	1000	1.44
1.85	694.4	1.0

1,000 gallons Imperial = 1,200 gallons U. S.

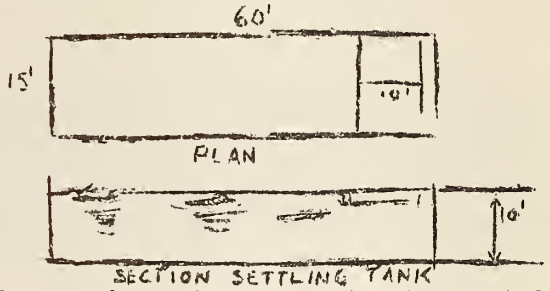
1 cubic foot of water weighs 62.4 pounds.

1 gallon of water weighs 10 lb.

1 cu. ft. of water contains 6.24 or nearly 6-1/4 gallons.

Detention Time, Surface Loading and Overflow Rate in a Settling Tank

Assume the flow rate is 1.35 m. g. d.



Detention time (assumed equal to the time required to fill the tank).

Rate of Flow = Q = 1.35 M. G. D. since 1 M.G.D. = 1.85 C.F.S.
Q = 1.35 x 1.85 = 2.5 C.F.S.

Volume of Tank = 60 x 15 x 10 = 9,000 cu. ft.

$$\text{Detention Time} = \frac{\text{Vol.}}{\text{Rate of Flow}} = \frac{9,000}{2.5} = 3,600 \text{ secs}$$
$$= 1 \text{ hour.}$$

Surface Loading:

Area of Surface = 60 x 15 = 900 sq. ft.

Flow Rate = 2.5 C.F.S. = 1,350,000 G. P. D.

$$\text{Therefore surface loading} = \frac{\text{Rate of Flow in G.P.D.}}{\text{Area of Surface in Tank}}$$
$$= \frac{1,350,000}{900} = \frac{13.5 \times 10^5}{9 \times 10^2} = 1.5 \times 10^3$$
$$= 1,500 \text{ gallons per day per sq. ft.}$$

Overflow Rate - Double Edged Weir

Length of overflow weir = 2 (15+15+10) = 40 feet x 2 = 80 feet.
Flow Rate = 1,350,000 gallons per day.
Therefore, overflow rate = $\frac{1.35 \times 10^6}{80} = 1.685 \times 10^4$

= 16,850 gal. per day per foot of weir.

Average or Mean:

The average or arithmetic mean of a series of measurements is calculated by dividing the sum of the measurements by the number of measurements.

e. g. If there are 24 readings spaced 1 hour apart, for the rate of flow through a plant, the average rate of flow is the sum of all the readings divided by 24.

Weighted Average:

If readings were taken at unequal intervals of time the readings which applied to two or three hour intervals should be treated as 2 or 3 identical readings - i. e. they should be multiplied by 2 or 3 in entering into the sum and they should be counted as 2 or 3 readings when calculating the number of readings.

Example - Suppose the average rate of pumping in million gallons per day is required. The pumps are adjusted at the beginning of each period and pump at a constant rate until the operator changes them and takes another reading. The readings are tabulated below in columns 1 and 2.

OBSERVATIONS

1 Hour	2 Rate of Pumping in M.G.D.	3 Weight	4 Product - Col. 2 x Col. 3
12 midnight	2.0	1	2.0
1 a. m.	2.5	2	5.0
3 a. m.	2.7	3	8.1
6 a. m.	3.0	1	3.0
7 a. m.	7.0	5	35.0
12 noon	6.0	2	12.0
2 p. m.	4.0	3	12.0
5 p. m.	3.0	4	12.0
9 p. m.	2.0	3	6.0
		24	95.1

A true average would not be obtained by merely adding Col. 2 and dividing by 9 because one of the readings applies to as long a period as 5 hours and so has 5 times the influence on the true average that a 1 hour reading would have and other readings apply to 2, 3 and 4 hour intervals.

Col. 3 tabulates the weight or duration of each reading and Col. 4 the weighted readings.

The weighted average is the sum of the weighted readings divided by the sum of the weights = $\frac{95.1}{24}$ = 3.96 m.g.d. Therefore the actual flow through the pumps in the 24 hour period was 3.96 million gallons.

Composite Sampling:

At the plant referred to in the previous example suppose that a composite sample of sewage pumped is required and that a sample is to be taken at each of the times listed.

If the same size of sample is taken each time, the strength from midnight to 1 a. m., when the rate of flow was only 2 M.G.D. would have the same influence on the total as the sample at 7 a. m. when the flow was 7 M.G.D. Obviously a true sewerage strength must be calculated from weighted samples.

Column 4 gives the relative volumes of sample to collect at each hour. The volume of the sample taken at 1 a. m. should be $\frac{5}{2}$ or $2\frac{1}{2}$ times as large as the volume of the midnight sample.

If each sample could be collected in its proper proportion and added to a bottle containing the samples previously collected and kept under refrigeration the composite sample at the end of 24 hours would represent in strength the average character of the pumped sewage.

In practice equal sizes of sample may be taken and placed in the refrigerator if the rate of flow at the time of sampling is marked on each bottle. Then the chemist can make up his own composite sample by taking a properly proportioned part out of each bottle according to the weighting calculated and shown in Col. 4.

Acknowledgements:

Much of the material used is based on "A Survey of Elementary Mathematics for Water and Sewage Works Operators" by Warren K. Eglof, PhD. (Published by Water and Sewage Works Magazine).

Another very useful booklet published by Water and Sewage Works Magazine is entitled "Hydraulics for the Practical Operator" by Robt. W. Angus, M. E.

SEWAGE WORKS OPERATORS' COURSE

S A F E T Y

February 24,1956

By L. E. Owers, P. Eng.

Introduction:

Occupational hazards in the operation of sewage works are considered to be above average. Not only are there hazards which require ordinary precautions, but also several which are peculiar to this type of work. Some of these are not well appreciated until a spectacular occurrence draws attention to them. While engineers give much thought to safety in their designs, there are a number of precautions which must be observed by the operators. The purpose of this paper is to inspire safety consciousness by a general discussion of the hazards and some of the desirable precautions.

Hazards:

Workers in sewers, sewage pumping stations, and sewage treatment plants are subjected to the following hazards:

1. Physical injuries
2. Body infections
3. Noxious gases and vapors
4. Oxygen deficiency.

The majority of accidents are included in the first two classifications.

To these may be added exposure to radioactivity from the use of radioactive materials which are expected to have increasing applications in industry and elsewhere. Future consideration to this additional problem will be necessary.

1. PHYSICAL INJURIES

1. Hazards in Sewers:

Traffic:

Access to sewers is usually on the street. Depending upon the traffic flow, signs, flag-men and manhole cages should be used during the work. Illumination is important at night and the service truck is useful for this as well as providing a traffic shield.

Equipment and Clothing:

Rubber footwear and gloves should be worn, preferably with other protective work clothing. If lighting is required an explosion proof lamp should be used. Where the manhole entered is greater than eight to ten feet deep, a safety belt should be worn and two men should be stationed at the surface.

The service truck should be equipped with a first aid kit. A supply of water for washing is also desirable. Emergency telephone numbers should be listed in the truck, and two-way telephone equipment can save valuable time.

Manhole:

Unless the manhole cover is oversize, it should be raised by one man using a special lifter. It should be completely removed and ·e placed flat away from the entrance. In descending the manhole, the worker should note the location and condition of rungs.

2. Hazards in Sewage Pumping Stations

Construction:

Frequently, sewage pumping stations are small and design requirements necessitate undesirable layouts. The use of warning signs or conspicuous painting for stairs and obstructions is recommended. Ladders are undesirable, but the use of hoop-cage enclosures reduces the risk when they are used in deep wells. Light colored paint is a useful adjunct to adequate artificial lighting.

Particularly where open electrical control panels are used, grounding and the use of rubber mats for the operators are important. Closed control boards are much more satisfactory.

A fire extinguisher should be conveniently located and be kept in good condition.

Maintenance:

Good housekeeping practices which include cleanliness and proper storage avoid many accidents. All electrical circuits should be kept in good repair. Guards for mechanical equipment and hatchways should be kept in position.

During repairs of electrical equipment, open switches should be tagged to avoid errors by other operators.

3. Hazards in Sewage Treatment Plants

The comments made regarding sewage pumping stations are equally applicable to treatment plants. Railings and catwalks should be kept clear and in good repair. For large tanks, a convenient life preserver is a wise precaution.

3. Hazards in Sewage Treatment Plants:(Cont.)

Personnel:

Probably the most important factor in working injuries is insufficient help for many jobs. This will be readily appreciated in the moving of heavy equipment. Training in first aid and drills for emergency situations increase personnel appreciation of safety needs.

2. BODY INFECTIONS

Transmissions:

In sewage works, there is direct exposure to infectious material. To prevent such material entering the body by way of the nose, mouth and eyes, the workman should remember to "keep his hands below his collar". Apart from explosion hazard, smoking is undesirable for this reason. Cuts should receive immediate attention regardless how small.

Prevention:

Personal cleanliness is very important in this work. Showers and a dressing room should be provided at the treatment plant. A separate lunch room where equipment may be provided to avoid the transmission of infectious material is desirable.

Cross Connections:

The only satisfactory protection against cross connection between the drinking water system and other piping in treatment plants or pumping stations is complete physical disconnection. Temporary cross connections such as leaving a hose submerged in a tank should also be avoided. Obviously, precautions in this regard are also necessary for the protection of the entire municipal water distribution system.

Inoculations:

All personnel for sewage works should be inoculated against typhoid and paratyphoid fevers. Inoculations can usually be arranged through the local health department, and must be repeated at intervals to preserve immunity.

3. NOXIOUS GASES AND VAPORS, AND OXYGEN DEFICIENCY

Description:

Oxygen deficiency is the commonest condition encountered in sewage works. The oxygen content of air may be reduced to a dangerous level by the presence of harmless as well as poisonous gases.

A number of gases such as hydrogen can produce an explosion if the gas-oxygen mixture is suitable and ignition occurs. The proportions of a gas-air mixture between which an explosion can occur are known as its explosive limits. Outside of these limits, only local combination at a source of ignition occurs. Gasolene in sewers has caused the most spectacular and destructive explosions.

3. NOXIOUS GASES AND VAPORS, AND OXYGEN DEFICIENCY (Cont.)

Poisonous gases are such gases as chlorine, carbon monoxide and hydrogen sulphide. Many poisonous gases are also flammable or suffocating.

"Sewer gas" is a common term referring to the gases of decomposition. Oxygen deficiency is the usual hazard if "sewer gas" is present, but an explosive mixture of methane may be found.

Occurence:

Conditions in this classification can be expected in the following locations:

In Sewers

1. Serving industry
2. Close to gasolene storage tanks or gas mains
3. Where manholes are greater than three hundred feet apart, particularly with solid manhold covers
4. With a flat grade
5. Deeper than eight to ten feet.

In Sewage pumping stations

1. In the dry well from fuel leakage from standby motors.
2. In the wet well at the outlet of sewers.

In Sewage Treatment Plants

1. At the plant inlet
2. Near digesters and sludge gas utilization equipment.
3. In poorly ventilated pits or tanks
4. In chlorination rooms.

Detection:

The sense of smell alone is useful but not reliable in the detection of hazardous gas conditions. A hazard may exist with no odor present. The following inexpensive detection equipment is recommended:

1. An oxygen deficiency indicator (this is an adaptation of the mine safety lamp)
2. An explosimeter
3. Ampoules for the detection of hydrogen sulphide and carbon monoxide.

Sewers:

Sewers should be thoroughly ventilated before entering. Ventilation can be improved by the use of a canopy, a stream of water or a portable blower. In emergencies, a gas mask preferably of the hose type should be used. A safety belt should be worn in case of doubt or if the sewer is deep. Sources of ignition should be avoided.

3. NOXIOUS GASES AND VAPORS, & OXYGEN DEFICIENCY (Cont.)

Sewage Pumping Stations:

The chief precaution needed in sewage pumping stations is the elimination of sources of ignition. Equipment including heaters and tools should be explosion proof or non-sparking. It is preferable that the dry well or pump pit be entirely separate or sealed off from the wet well. It should also be well ventilated. Good maintenance of gasoline standby motors is essential to avoid fuel leakage.

Sewage Treatment Plants:

Digesters:

It is important to remember that gases of decomposition are often odorless. Therefore, good ventilation and constant precautions to avoid sources of ignition near digesters, open or closed sludge storage tanks, and gas utilization equipment are essential. Many safety devices such as explosion-proof motors and lighting, and condensate and flame traps are incorporated in these systems. These should be well maintained and external venting of gases be arranged in case of equipment failure. Large gas utilization systems are often located in separate explosion proof structures. Automatic alarm systems which are adaptations of explosimeters can be installed.

During work on sludge piping or pumps, the digester should be valved off. No piping which contains sludge should be completely isolated by valves due to possible mechanical failure from internal gas pressure.

Leakage of sludge gas may be readily located by the use of an explosimeter equipped with a probe. If such a device is not available, a soap solution applied at suspected points will usually detect the leak.

Chlorination Equipment:

An increasing number of sewage treatment plants is applying chlorine at some point in the system. This gas is readily detected by its choking odor and even slight exposure is sufficient to convince a person of its dangerous nature. Suppliers of this gas provide detailed information on it and all operators should become completely familiar with the recommended handling procedures.

Wherever possible, chlorine rooms should be separate. Good ventilation should be provided, and control valves and switches should be accessible without entering the room. Leaks should be repaired at once. The detection of these leaks is simple by means of ammonium hydroxide which produces white fumes when exposed to the gas.

SEWER ORDINANCES

The establishment and enforcement of municipal sewer ordinances is an important tool in the control of wastes discharged to a sewage system. Hazards produced by the indiscriminate discharge of industrial wastes can be reduced.

SAFETY PROGRAMS

Safety programs in sewage works are not common. The chief obstacle in establishing such programs is the small staff usually involved. The following suggestions are offered for application in all systems:

1. Safety consciousness be established in yourself. Your fellow employees or your staff by discussion and examination of safety information.

2. Hazards be reported and corrected wherever possible.

3. Good work habits be practiced and taught.

The requirements of safe operation are basic good design, safe practices, and knowledge and use of safety equipment.

BENEFITS

The benefits of safe operation apply to the entire organization and include:

1. Improved efficiency and service
2. Improved earnings
3. Better morale
4. Better public relations.

"Safety is no Accident"

A discussion of safety is completely embraced by this short statement.

In one sense, its interpretation provides a definition of safety and in another, an objective of safety. However, it is felt that the most important implication is that safe practices do not just happen, they are the result of thoughtful application of sound principles.

SEWAGE WORKS OPERATORS' COURSE No. 1

FEBRUARY 20-24, 1956

SUBJECT: ENTERIC DISEASES

Instructor: A. S. O'Hara, C.D., F.R.S.H., F.A.P.H.A.
Sanitation Consultant,
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The enteric diseases are also known as "the excremental group" or communicable diseases, because the germs which cause these diseases are to be found in the fecec and urine of infected persons.

The classical examples or diseases of the excremental group are typhoid fever and Asiatic cholera, to these we can add amoebic and bacillary dysentery, paratyphoid fever and the infections associated with a large group of germs which we call the "salmonellae." In recent years it has also been established that the virus which causes poliomyelitis, and that of infectious hepatitis may also be transmitted through the intestinal discharges of man. Finally, we can also include in the excremental diseases those conditions which are caused by worms; tapeworm and pinworm being examples.

The ancients developed sewerage systems to remove offensive smelling wastes from their communities. The moderns learned that removal was not enough, that sewage must be treated or illness developed, the sewage treatment operator is now a forward defence man in protecting his communities from epidemics. This statement may be expanded by saying that wherever, due to inefficient sewage systems or treatment, human wastes can gain access to drinking water or food, there is a strong possibility that an outbreak of one or more of the diseases which we are discussing will occur.

We in public health speak of the "Five F's" of the excremental diseases, which are:

Flies
Food
Faeces
Fingers
Fomites (articles in contact with a patient)

Flies, and sometimes roaches, feeding upon fecal matter will mechanically transfer infection to unprotected foodstuffs.

Food can be infected in a variety of ways by direct contact with polluted water or sewage. Here one recalls an outbreak of paratyphoid fever caused by a drain backing up and flooding an icehouse, the ice subsequently used in drinking water. Again, an infected person may handle food, especially

milk, milk products or cooked meats and so be the means of spreading his infection to others. In this respect, it is well to remember that a patient can suffer an attack of typhoid fever and clinically recover, but continue to harbour the germs for a long time afterwards. In the case of typhoid fever 2% to 3% of patients remain carriers. This carrier state is not confined to typhoid fever, it occurs in other diseases of the same group, notably dysentery and cholera.

The prime purpose of sewage systems and treatment, as we have seen, is to prevent wastes from gaining access to drinking water or anything else which may be consumed by man. The germs which cause the diseases of the excremental group must be swallowed in order to produce infection. In this regard they are unlike the germs which cause diphtheria and whooping cough as these lodge in the respiratory and not the intestinal tract, or those causing malaria and yellow fever which are directly transmitted to the blood stream by inoculation due to mosquito bites.

From the foregoing, one would assume, and correctly, that sewage works operators are exposed to a great variety of infections in the course of their daily work. The question logically arises that since operators should be protected against infection, what are the best means of so doing?

Obviously, the first requisite is an operator in good general health, since a person in sound physical health is less likely to contract infection from any source than one who is chronically ailing. This is ensured by the regular medical check-up and by faithful attention to the physician's advice.

The next protection which the operator has is that modern sewage treatment plants do not involve the operator in much direct contact with the wastes.

Again, the practice of good personal hygiene, more especially regular hand-washing, constitutes an important deterrent to infection. One also assumes that the modern operator keeps his working clothes in his locker at the plant, and does not wear them home; that the plant provides lockers for his street clothing and also showers for his bodily cleanliness; that if he eats his lunch at the plant, a separate room is provided for this purpose.

Additionally, the operator can be protected by vaccines against typhoid and paratyphoid fever and poliomyelitis. The protection thus afforded is valuable. Similarly, it would be good policy to receive protection against tetanus (lock jaw). Your family or plant physician or local medical officer of health can advise you further on these matters.

SEWAGE WORKS OPERATORS' COURSE NO.1

February 20-24, 1956

SUBJECT: LEGISLATION

Instructor: A.E. Berry

INTRODUCTION:

The operation of sewage works is concerned with a good deal of legislation. A knowledge of this legislation is important. Operators must know something about their authority and responsibilities in the operation of sewage works. This legislation may serve different purposes from safeguarding the public health to making sure that these systems are installed in a manner which will give a minimum of inconvenience.

LEGISLATION APPLICABLE TO SEWAGE WORKS:

Several Provincial statutes are applicable to this field. Local by-laws and rules may also be passed by Councils.

A clear understanding is necessary in respect to local authority. Municipalities and various Departments of municipalities derive their authority entirely from the Province. They cannot act without this. Similarly, this legislation places obligations on municipal bodies. Much of the legislation in force at the Provincial level is a permissive type in that it authorizes the passing of local by-laws and rules which may be applicable to that municipality only.

SOME OF THESE ACTS INCLUDE THE FOLLOWING:

(a) The Public Health Act.
(b) The Municipal Act.
(c) The Local Improvement Act.
(d) Act Pertaining to Pollution Control.
(e) Other Acts dealing less directly with Sewage Works.

SOME OF THE MAIN FEATURES OF THESE ACTS:

THE PUBLIC HEALTH ACT:

A number of the sections of The Public Health Act are significant in the operation of sewage works.

1. The Provincial Department of Health has supervision over public sewerage systems. This includes their installation and maintenance. It is designed primarily to protect health and to prevent pollution of water supplies.

This must be a co-operative effort between the Department and the operators in which the knowledge and skill of each

are put to best advantage. See Sections 103, 105, 106, 107, 108, 109, 111, and 112. Also, Section 23, Sub-section 2. Certain other parts of The Public Health Act have a bearing on sewage works.

(a) Installation of Sewage Works:

Approval is required for the installation of a new sewer system or any extension thereto. This includes all sewers, pumping stations, treatment plants, outfalls and all other parts of the system. This requirement is the same whether the cost is paid from current revenue or whether debentures are to be issued for this.

(b) This is to be at all times subject to the approval and direction of the Department. See Section 111.

(c) Mandatory Orders:

The Department may issue Mandatory Orders to compel the installation or alteration of a sewage works. See Section 109. In that case, no assent of the electors is required for the issue of debentures or for undertaking the work.

(d) Disposal of Wastes:

The Act prohibits pollution of watercourses by garbage, excreta, manure, vegetable or animal matter or filth. See Section 103. This is further amplified in Section 105.

(e) Borrowing Money for Sewage Works:

Where expenditures are not to be paid from current revenue and debentures are to be issued, approval of the Municipal Board is required as well as that of the Department of Health.

(f) Extension of Sewerage Project to Adjacent Municipality:

Where a "Sewerage Project" of an urban municipality is to be extended into a rural municipality, Section 106 of The Public Health Act requires the Provincial Department of Health to hold a hearing and to review any complaints that may be made against the proposal.

POLICY OF THE DEPARTMENT OF HEALTH:

The policy of the Department of Health is to prescribe standards or requirements for sewage works to suit the local needs. Then the operator is expected to secure the desired results from those sewage works. It is not considered feasible to set one minimum standard applicable to all cases. Thus, where there is a large body of water into which the effluent from a sewage treatment plant can be discharged, the degree of treatment will be considerably less than that needed under other circumstances. The laboratories of the Department and the personnel are available to assist operators and municipal officials in carrying out their programmes in the sewerage field.

LOCAL HEALTH AGENCIES:

Every municipality in the Province is expected to have a Medical Officer of Health and a Board of Health. The M.O.H. has wide powers under The Public Health Act to deal with anything which may affect health or spread disease.

The Sanitary Inspectors work under the direction of the Medical Officer of Health. They will collect samples and send them to the Branch Laboratories for chemical and bacteriological tests.

The laboratories of the Department are located at various places in the Province. All routine bacteriolcgical samples may be sent to these laboratories while other tests, including chemical, physical and biological as well as bacteriological, may be made at the Experimental Station of the Department located at 807 Richmond Street West, Toronto.

The local Medical Officer of Health will supplement the supervision over sewage works given by the Provincial Department of Health. The local M.O.H. is concerned with the control of pollution and safeguarding of water supplies which may be used for drinking purposes, for recreation or for anything else which may concern public health. He deals with such problems as:

(a) Sewer Connection to Premises:

Under Section 23, Sub-section 2 of The Public Health Act, the Medical Officer of Health may take action to have premises connected to the municipal sewer and to have septic tanks abandoned.

(b) Nuisances:

Anything which may injuriously affect health may be classed as a nuisance and be dealt with by the Health Officer. This would include drainage, sewage, industrial wastes etc.

Co-operation between the operator and the local health agencies can be helpful to both parties. It is desirable for the operator to know the Health Officer, the Sanitary Inspector, and to be familiar with their authority and procedures.

THE MUNICIPAL ACT:

This comprehensive Act sets municipal requirements and authorizes by-laws and practices to be adopted under local jurisdiction. Much of this is permissive legislation giving certain authority to municipal Councils and other local agencies.

THE RIGHT TO PASS BY-LAWS:

By-laws may be passed by the Councils of local municipalities and dealing with a number of subjects. Sections 386 and 388 specify subjects which may be covered in this way.

Section 388, Sub-section 66, provides for completing, extending or altering a sewerage system on approval by vote by three-quarters of all Members of Council.

Section 388, Sub-section 119 (a), permits Councils to pass by-laws regulating the discharge of wastes into any sewer system.

Section 386, Sub-section 5, makes it possible to provide by by-law for joint operation by municipalities of sewerage systems.

Section 388, Sub-section 32, authorizes the closing of private sewage disposal systems.

MONEY BY-LAWS:

The procedure for voting on money by-laws of all kinds is given in Section 298.

Section 389 deals with sewer rates and sewage service rates as means for raising the money to finance sewage works systems.

These are but some of the various parts of The Municipal Act which are applicable to the installation and operation of sewage works systems. It is well that the operator be familiar with the main parts of The Municipal Act as well as its application to sewage works in general.

THE LOCAL IMPROVEMENT ACT:

This Act is used extensively for the construction of sewers. The Basis of it is that the sewers are paid for on a frontage rate and the sewers may be constructed to serve one area of a municipality so that the cost will be borne largely by that area rather than by the municipality at large.

LEGISLATION PERTAINING TO POLLUTION CONTROL:

Several Acts of the Province have sections pertaining to pollution control. These may be applicable to pollution which will be of concern to certain groups. As an example, The Public Health Act deals with pollution which may affect public health. The Department of Lands and Forests utilize legislation which is concerned with pollution which may injuriously affect fish and wild like. Similarly, other Departments such as Agriculture, Mining, and Planning and Development have legislation dealing with pollution control.

THE POLLUTION CONTROL BOARD:

In order to deal with pollution in all its aspects in Ontario, The Pollution Control Board has been created. It consists of representatives from various Departments of Government which are concerned with pollution effects of any kinds. In this way it is possible to deal jointly with pollution irrespective of the particular interest it affects. The Board has adopted objectives for water quality. These deal with the condition of the effluent from sewage treatment plants and from industrial waste treatment plants as they are discharged to watercourses of the Province. It will be noted these are objectives and are not hard and fast standards which are set down as a Legislative requirement.

LEGISLATION IN GENERAL:

It will be seen that there is much legislation in this Province which affects the operation of sewage works and industrial waste treatment processes. Every operator of sewage works, irrespective of the kind of works he is dealing with, should have some general knowledge of the principles involved in the legislation and should know where to look for authority for doing certain activities.

SEWAGE WORKS OPERATORS' COURSE NO. 1

February 20-24, 1956

SUBJECT: INDUSTRIAL WASTES - MUNICIPAL BY-LAWS

Instructor: E. G. Hachborn

Sewage Treatment Plants have been plagued for many years by the discharge of potent industrial waste into the municipal sewerage system, Such plants are probably the most abused through misuse of all public utilities. The causes of this situation are:

1. The disregard for their limitations and capacities and the misbelief that a sewer can carry away any unwanted substances or objects and that the treatment plants will take care of them;

2. A lack of regulations setting forth the uses and limitations of the system;

3. The failure of municipal authorities to enforce what regulations prevail.

The purpose of this paper is to make operators more conscious of the importance of controlled usage of sewers and to assure them that it is possible to control the discharge of industrial waste to the point where their task of operating a sewage treatment plant is made easier. Mr. DeLaporte has discussed with you the effect of various types of waste on the operation of a Sewage Treatment Plant and I hope that this paper will give some enlightenment on the limitations that should be placed upon industries and other offenders to eliminate some of the treatment problems and to realize the intended use for which the sewerage system and the Sewage Treatment Plant are designed. I will try and discuss the problem at hand in as orderly a fashion as possible and I think that perhaps we might tackle the problem under the following headings:

A. The reasons why controlled usage of sewers is necessary.
B. What considerations must be given to the offending industry and who decides them?
C. How will we handle the problem of accepting or rejecting the waste?
D. Who should draft a By-Law for the regulation of waste discharge?
E. The composition of the By-Law and limitations.
F. Enforcement and penalties.

A. The reasons why controlled usage of sewers is necessary.

In this highly industrialized age, it is becoming more important that municipalities have regard for the possible menace to public health and safety, potential damage to the system and increased cost of maintenance and operation, caused by the indiscriminate discharge of these potent wastes. With the present trend on the part of municipalities to attract industry to establish and build in their cities, some form of ordinance, for controlled usage of sewers becomes more important than ever. In the past, at the time of this inducement probably very little thought had been given to the volume, character or effect of the wastes discharged by the industry. As Mr. DeLaporte has probably pointed out, the results have been serious both to the community and to the industry. We are concerned mostly, however, with the results to the Sewage Treatment Plants and the headaches which are caused to their operators. The enforcement of an ordinance is not as serious as it might sound and in many cases, industries have benefited by the use of by-products recovered from the wastes which they were allowed to discharge prior to the existence of an ordinance It is unlikely that any ordinance or workable formula can be devised which will be applicable to all cities in the Province and it is usual that the co-operation that is necessary for the proper enforcement of regulations would be most helpful in outlining the benefits which will result. It is also very helpful to the plant operator if industries will do research on the problem, which research will usually present some solution as well as indicate possible recovery of by-products, whose value will often pay for the cost of treatment facilities, which they might be required to install.

The effects on sewage treatment processes are many. Some of these might be low pH values, clogging due to hair or felt, matting due to scum or grease, not to mention the effects of high concentrations of suspended solids or B.O.D. A sound ordinance can usually be beneficial to both the industry and the municipality by making possible the maximum use of public facilities for all wastes which can be handled effectively. The operator might not agree with this policy. However, our approach must be a realistic one and we must remember that industries have a beneficial effect on the community in spite of a somewhat detrimental effect on the Sewage Treatment Plant. I am not implying that the industry should be permitted to discharge its waste with no regard for the plant capacity, but feel that if their waste can be accommodated without too great an effect, it would be to everyone's advantage to do so, and even in some cases the industry could be billed the cost of taking care of the additional load on the plant, for which they are responsible.

B. What consideration must be given to the offending industry and who decides them?

Before writing a set of rules, certain preliminary considerations should be given. Most existing public health By-laws prohibit the discharge into public sewers of any materials which in the opinion of the City Engineer, are not in the interest of public health. Today, such a clause would be very inadequate, except in perhaps the very smallest of communities. Maybe the sewage plant operator is the one to decide what materials should be banned from the sewers. Certainly he is more aware firsthand of their effect than possibly the City Engineer would be. Certainly the delegation of a municipal officer to decide acceptable wastes has many advantages. I believe the sewage plant operator would prove a great help in deciding such. This would tend to make the arrangement more flexible and also gets away from arbitrary limits which are often unfair. Technical advice should be sought in deciding some specific limits and permissible variations of waste characters inasmuch as these limits will offer guidance and support to the official responsible.

It is not fair to eliminate all industrial waste, as I have mentioned before, since they are not all objectionable. However, the plant and the sewerage system should be used, maintained and operated in the public interest, which would make it unwise to permit a use which would result in either physical damage, operational problems or excessive maintenance cost. These limitations should not be overlooked in a desire to protect an industry for its beneficial effects to taxes and payroll.

It is not the intention of this paper to make solicitors out of the operators so that they themselves could write the ordinance, but the operator should understand clearly industry's point of view, since his opinions will probably carry great weight in discussions preparatory to setting for th limitations beyond which the effect of the plant operation is detrimental.

C. How will we handle the problem of accepting or rejecting the waste?

There are three methods of handling the problem mainly:

1. The city accepts all wastes and assumes full responsibility for its treatment, either at its own expense or with special charges to the industry;

2. The city rejects all industrial waste and holds the industry fully responsible for its treatment and disposal.

3. A combination of the two, whereby industrial wastes are controlled and modified at the source, rendering them acceptable into the city's system.

Industry would prefer the first method. They would rather pay the municipality than treat their own waste, since they are primarily interested in manufacturing and not in sewage treatment. This is unfair to the general public and needless to say causes considerable grief to the sewage treatment plant operator, since the plants are often designed to treat domestic volumes and strengths of sewage, and if called upon to serve industry, the increased load may cause them to fail in fulfilling their prime function.

In relieving the offending industry, it would probably offer little or no restraint from additional pollution. The second method would be municipal suicide and even if complete elimination of all industrial waste could be realized, probably the only person who would seem very much happier would be the sewage treatment plant operator himself.

Therefore, it seems that we should admit wastes which are not more objectionable than domestic sewage and therefore require industry to give preliminary treatment which would render the initial waste acceptable. This seems the fairest method to both city and management and the problems can be decided on their own merits. The sewage plant operator in this case shouls also be able to cope with this problem, without undue worry and grief.

Wastes which are extremely dangerous because of their flammable nature, or for any other reason that would cause serious physical damage to collection, or treatment facilities, should be excluded entirely. If such a move were acceptable, costs of treatment by municipalities would be in line with the cost of treating normal domestic sewage and industry would have to bear the cost of pretreatment, if necessary, or other means of disposal, if the waste is excluded.

A discussion of charges for such a service is not within the scope of this paper; nevertheless, the establishment of proper regulations provides the basis for fair economic considerations since practically all wastes entering the system will be equally acceptable and for economic purposes practically equal in effect. If some waste is accepted without pretreatment which still presents a problem to the municipality, it is often a simple matter to impose a surcharge on the

industry's tax, based on the strength of the waste over and above that of a normal domestic sewage.

It is quite apparent that a proper set of regulations, such as are discussed further on this paper, can only be had after a complete study has been made of the problems involved at each industrial plant and at the municipal sewage treatment plant. The limits should be practicable and no more rigid than will be necessary to protect the system and its operation. Industries, it is true, know their own wastes, but have little knowledge of their effect on the municipal plant, and in order to set a standard for acceptable discharges, a comprehensive study of flows and analysis is necessary. Often the analysis of industrial wastes shows poor housekeeping to prevail in the plants which, when corrected by proper recovery methods, can go far in paying for preliminary treatment.

D. Who should draft a By-law for the regulation of waste discharge?

It would seem that a modern by-law would have to be given very serious consideration by a special committee appointed by the municipal governing body. The Municipal Engineer, with his professional knowledge and practical experience usually heads such a committee and it would seem desirable to also have on it consulting engineers or chemists as well as supervisory officials in the community who have technical or chemical experience. If the City Engineer or Superintendent of Sewage Treatment is not experienced on industrial waste problems, they would certainly know where to secure the necessary information and evaluate the discussions which might ensue. As previously mentioned, the sewage plant operator can help greatly in the considerations necessary regarding limitations consistent with plant operation.

It is felt that the Chamber of Commerce should be interested in the drafting of a by-law since it would be in their interest to be able to choose a proper location within the general metropolitan area of a city where industry may locate with a minimum of sewer problems. Industry should have a representative on such a committee since it is interested in serving the community.

Industries object to being barred from the use of municipal facilities, but it is felt, however, that in most cases they do not seek unfair advantages for themselves. From past experience in some American cities, pollution abatement by strict governmental order is poor public relations. This also applies to the elimination of industrial waste overloadings and it is certain that research,

the exchange of "know-how" and considerable public goodwill, as well as an intelligent aggressive attitude on the part of industry, will go far in the establishment of a workable ordinance. Proof of this statement was demonstrated at the Industrial Wastes Conference held at Purdue University in 1949, where the following reasons were given for the poor collaboration in evidence in many cities regarding municipal industrial wastes ordinance.

1. The unreasonable attitude of the municipality to accept normal wastes.

2. Improper preliminary analysis of industrial wastes and plant conditions.

3. Non-familiarity with industrial operation.

4. A poor ordinance. No delineation of characteristics of acceptable wastes.

5. Stubborness in accommodating certain wastes by the sewage treatment plant personnel.

6. Poor control by industry over pretreatment or failure to give prompt notice to the municipality of accidental losses due to breakdowns, etc.

7. Unwillingness of industry to bear costs of pretreatment.

8. Lack of interest by both parites in each other's problems, often compounded with suspicion and mistrust.

Let us bear these in mind if we are faced with the preparation or enforcement of municipal ordinances on industrial wastes.

E. The composition of the by-law and limitations.

The composition of an industrial waste by-law will vary in each municipality and this particular section will be one of the many in a complete sewer ordinance properly introduced and providing penalties for violation. This document should also define all terms used therein in order to eliminate differences of interpretation that might result in dispute or litigation.

Five main points to consider when formulating an industrial waste standard are as follows:

1. Method of collection and segregation of unwanted wastes.

2. Wastes causing structural damage.

3. Wastes containing oils and greases.

4. Wastes with high B.O.D.

5. Toxic wastes.

To facilitate testing and control, industrial wastes should be segregated at least to a point where sampling is possible. It is suggested that a control manhole be provided where industrial wastes enter the main sewer. Often it is best to segregate industrial waste from the sanitary sewage arising in a plant. This would permit control over industrial wastes discharged, by way of permitting suspension without depriving the plant of its sanitary facilities.

It is always best to segregate storm waters, of course, although spillage which becomes contaminated, in the case of open air industries, should enter the sewers. Provision should be made to segregate unwanted waste, that is, materials normally foreign to the system. This would include sand, metal filings, heavy sludges, etc. Discharge of process or cooling waters must be guarded against for fear of imposing heavy overloads on existing capacities. Temperature should be limited to protect jointing compounds and not interfere with biological activity. Detroit suggests a maximum temperature of 150°F. Waste causing structural damage would include acid waste and waste containing, or producing, sulphides. This is usually guarded against by stipulating a minimum pH of 6.0. The temperature limitation is also a protection against structural damage by way of eliminating joint softening. Alkaline wastes seldom cause serious problems.

Oils and greases are becoming more serious with the increased use of detergents and emulsified agents in the home and industry. The Sanitation District of Los Angeles County classifies oils and greases as either floating or dispersed, and limits floatable oils to 10 p.p.m. Vegetable oils are permitted to a concentration of 25 p.p.m., whereas well dispersed oils are normally allowed up to 600 p.p.m. However, the emulsion must be stable and not be broken by further dilutions and further pH changes.

Several limitations have been set on B.O.D.'s 0.17 lbs. per capita was considered at one time to be the normal

content for domestic sewage. This would vary, of course, with water consumption, but would be equivalent to approximately 200 p.p.m. based on 100 gallons per capita daily flow. It has been suggested that 300 p.p.m. would be a reasonable maximum. By the same approach, 350 p.p.m. suspended solids is a representative content.

F. Enforcement and penalties.

Proper enforcement is essential if the ordinance is to fulfil its intended purpose. In larger cities where sewage collection and treatment are under one department, the head of such department is usually the one to enforce such. The Federation of Sewage Works Association suggests that full responsibility be delegated to one individual who might be titled Superintendent of Sewage Works. In smaller municipalities, he may have to call upon the services of a capable consulting sanitary engineer or chemist.

It is necessary to decide upon a maximum penalty that would serve to deter wilful continued or occasional violation by an offender who might find payment of the penalty less expensive than compliance. Those set forth in various ordinances vary from a minimum of $1.00 to a maximum of $500.00 A maximum of $200.00 has been suggested.

Prosecution procedure is provided for automatically when the ordinance receives its official passage in the municipality. However, it would be best that a notice of violation fix a definite time limit for correction of the objectionable condition. This would be best varied to suit the nature and the extent of the necessary improvement.

INDUSTRIAL WASTES

A. V. DeLaporte

Industrial wastes for this lecture are divided into four groups. These are well explained in the "Objectives for Water Quality Control", a publication available from the Ontario Water Resources Commission.

A. Excessive bacterial, physical or chemical contamination.

B. Unnatural deposits in the stream interfering with navigation, fish and wild life, bathing, recreation or destruction of aesthetic values.

C. Toxic substances and materials imparting objectionable tastes and odors to waters and for domestic or indust ial purposes.

D. Floating material - including oil, grease, garbage, sewage solids, or other refuse.

Specific Objectives:

In more specific terms adequate control of pollution will necessitate the following objectives.

A. Sanitary Sewage, storm water and wastes from water craft and need not be discussed here.

B(1) Chemical wastes - Phenolic type - this includes wastes from C and Rc, synthetic resin, oil refining, petroleum cracking, tar, road oil, creosoting, wood distillation, dye manufacturing and certain types of paper board plants.

Page 65 of the International Joint Commission Report of 1951 states:

"Certain Industrial Wastes are known to cause objectionable tastes and odors in drinking waters. Many of the wastes in this section are complex in chemical structure, and insufficient information was available on their behaviour when subjected to water treatment processes, particularly chlorination. Since it was believed that analytical methods alone would not give a complete measure of their taste producing properties, it was deemed essential to undertake a special investigation of this problem."

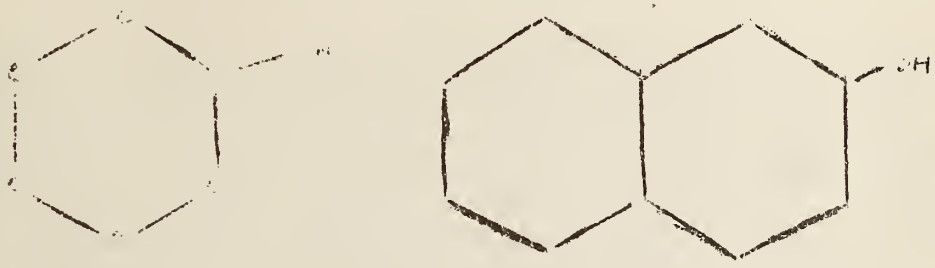
In order that an industrial waste may affect a water supply:

(1) the waste must be of sufficient volume and must possess sufficient potency of the taste and odor producing substances to either alone or when combined with other wastes, to withstand intermediate dilution.

(2) the constituents of the wastes responsible for the taste must be able to persist continuously or periodically, though transportation from the point of discharge to the affected water works intake.

Conclusion 3. Chlorination tests on the various wastes for development and persistence of taste were made, using varying dosages of chlorine. These showed that the measure of phenolic material, regardless of analytical technique does not necessarily reveal its ability to produce taste upon chlorination.

Phenols or phenolic equivalents for our purpose comprise all compounds which react with Gibb's reagent. These compounds are generally very aromatic. They taint the flesh of fish and are toxic to fish depending on the concentration. Normal water does not contain phenol.



To eliminate these compounds it is necessary to break the benzene ring. Oxidation of the compound is the simplest method. Oxidation can be accomplished biologically (bio oxidation) by chlorination - by using chlorine dioxide - or ozone.

B(2) Chemical wastes other than phenolic.

Industries producing wastes of this type are oil wells, petroleum refineries, gasoline filling stations, bulk station styrene copolymer, synthetic pharmaceutical, synthetic fibre, iron and steel, alkali chemical, rubber fabricating dye manufacturing and acid manufacturing plants.

Chemical wastes have different effects on water. The alkali plants may raise the pH to an undesirable level. Acid plants and pickling liquors from steel or iron works may lower the pH significantly. The pickling liquors contain iron salts. The iron will generally be precipitated on dilution and from undesirable deposits and may also lower the dissolved oxygen by the oxidation of the ferrous salts to ferric salts.

Wastes from some copolymers, and synthetic pharmaceutical plants may have odor producing substances that will have a very deleterious effect on the water quality, Colour from dye works or textile industries and suspended matter from any of the above industries may well make the receiving water offensive in appearance. Oils and floating solids create a fire hazard injurious to fish and wildlife or their habitat and will adversely affect recreational development and other shoreline uses.

(3) Highly toxic wastes;

This type of waste generally comes from metal plating and finishing chemical or pharmaceutical plants, coke ovens and chemical works producing free halogens, i.e. chlorine.

The OWRC water quality objective asks that these substances be eliminated, that is reduced to a point where by present methods of analysis no significant figure can be observed.

(4) Deoxygenating Wastes:

Some of the industries producing these wastes are: tanneries, glue and gelatin plants, alcohol, including breweries and distrilleries, wool scouring, pulp and paper, food processing plants, such as meat packing, dairy plants, corn products, beet sugar, fish processing and dehydration plants. In addition to those organic wastes, wastes containing ferrous iron salts will use dissolved oxygen to convert the "ous" iron to ferric iron thus causing depletion of the available oxygen.

This type of waste is generally the primary cause of nuisance due to the anaerobic condition caused in the receiving waters. Anerobic and facultative anaerobic organisms will get their required oxygen from the dissolved mineral salts reducing sulfates to sulfides. Sulfides are malodorous.

There are two more points I want to emphasize. The first is a bacteriological one as such should be in the bacteriological course; but I have found most bacteriological courses ignored. All life as we know it, requires oxygen. The so-called anaerobes and facultative anaerobes, whichever the bacteriologist cares to call them, posses the ability to secure oxygen from chemical entities containing oxygen in their structure.

The second point I want to emphasize is that traces of organic compounds in concentrations of a few parts per billion are present in all natural water. Where the water contains contamination either by sanitary sewage or industrial wastes the concentration of trace organics is

increased - e.g. at Pt. Elgin 15 p.p.b., Sarnia - 30 p.p.b., Wallaceburg - 70 p.p.b., and due to oxidation and dilution, at Windsor - 30 p.p.b. Some of these compounds are not oxydized by the natural purification processes and we have evidence of the persistence over long periods of time. There is no information on the effect of the ingestion of traces of these compounds over a period of time on the metabolism of the animal using the water. Nor for that matter is there information on the chemical structure of some of the pollutive material.

Ontario Water Resources Commission
MOE/SEW/AROU
Sewage Works Operators Course No. 1.
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